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Eight Instructional Tests span the curriculum of one year of biology study. The first concerned the Nature of Science and included 4 areas of emphasis: the nature and function of hypothesis and idea of controls in experiments, interpretation of graphed data, and the nature of data. The second test was designed to show an understanding of Biological classification with 3 areas of emphasis: relations of taxonomic groups, the basis of biological classification, and the concept of species.

The third test considered the changes in living things with the following areas of emphasis: evaluation, spontaneous generation, adaptation, variation, and the nature of science. The fourth test covers the chemical basis of biology, with emphasis on understanding of selected ideas regarding unity in living things; and ways in which molecules and ions move or are transported in living things.

The fifth test concerned the cell and photosynthesis, containing 4 major areas of emphasis: the cell, cell division, photosynthesis and enzymes. The sixth test is a final exam for the first semester, comprising: the nature of scientific inquiry, the theory of evolution, cell biology and multicellular organisms. The sixth test develops 4 areas of genetics; historical development of themodern gene theory, probability, Menelian genetics, and biochemical aspects of genetics, evolution, genetics, energy relations, development, ecology, reproduction, nature of science, history of biological concepts and regulatory mechanisms.

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AS DETERMINED BY INSTRUCTIONAL TESTS

ED001141

Cooperative Research Project
No. 1969

JAMES T. ROBINSON

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CLAREMONT GRADUATE SCHOOL
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LOS ANGELES COUNTY SUPERINTENDENT
OF SCHOOLS OFFICE

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UNDERSTANDINGS OF BSCS BIOLOGY STUDENTS AS DETERMINED BY INSTRUCTIONAL TESTS

Cooperative Research Project No. 1969

James T. Robinson

Claremont Graduate School
and University Center
Claremont, California

in cooperation with the

Los Angeles County Superintendent
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Los Angeles, California

1964

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As the first chapter will indicate, this project began with a request that the writer assist the Los Angeles County BSCS Blue Version Test Center with the development of tests for instructional use. During 1961-62 the writer had the opportunity to discuss this project with Dr. Harry Passow, Horace Mann Institute, and Dr. Ralph Tyler, Director, Center for Advanced Study in the Behavioral Sciences, and was encouraged to develop a proposal for submission to the United States Office of Education, Cooperative Research Branch. Since such a proposal requires the cooperation of an institution of higher learning, the writer was particularly pleased when Dr. Arthur King and Dr. John Brownell of the Claremont Graduate School and University Center agreed to join with the Office of the Los Angeles County Superintendent of Schools in sponsoring this study. Dr. C. C. Trillingham, Los Angeles County Schools Superintendent, and members of his staff facilitated the work of the project in many ways, and this office was particularly helpful in making the time of the writer available for this research.

In January of 1962 the writer was privileged to discuss the project with Dr. Arnold Grobman, Director of Biological Sciences Curriculum Study, and was encouraged by his interest and support for this research.

During the early stages of test development the writer found particularly helpful the publication by Educational Testing Service, Questions and Problems in Science, Test Item Folio No. 1 by

Paul L. Dressel and Clarence H. Nelson. Several questions in this report had their origins in questions in the folio, and Test 44, Part 3, was modified from a question series in the folio.

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J.T.R.

Los Angeles County Schools Office
Los Angeles, California

CONTENTS

ACKNOWLEDGEMENTS iii

CONTENTS v

LIST OF TABLES vii

LIST OF ILLUSTRATIONS xi

Chapter Page

I. BACKGROUND AND DEVELOPMENT OF THE STUDY 1

Background of the Project
Organization for the Development of Instructional Tests
Research Design

II. PRESENTATION AND ANALYSIS OF BACKGROUND DATA ON THE STUDENT POPULATION AND THE TEXTBOOK 21

The Selection of Data for Analysis
The Student Population
School Standardized Test Data
Differential Aptitude Test Data

III. THE INSTRUCTIONAL TESTS 41

Test 41, The Nature of Science
Test 42, Understanding Biological Classification
Test 43, Changes in Living Things
Test 44, The Chemical Basis of Biology
Test 46, The Cell and Photosynthesis
Test 48, First Semester Final Examination
Test 49, Genetics
Test 55, Year Ending Final Examination

IV. ASPECTS OF THE READABILITY OF BLUE VERSION MATERIALS . . 293

Some Findings on the Readability of the 1961 and 1963 Editions of the Blue Version
Thoughts on the "'Is' of Identity"
Magazine Reading of Students
Comments and Conclusions

CONTENTS--continued

Chapter | Page

V. CONCLUSIONS AND RECOMMENDATIONS 315

Levels of Student Understanding
Findings Regarding the Proposed Problems
The Development of Instructional Tests
Recommendations for Further Study

APPENDIX A 335

APPENDIX B 357

REFERENCES CITED 361

LIST OF TABLES

Table Page

1.1 The Student Population 8

1.2 The Instructional Materials 10

1.3 The Instructional Tests 12

1.4 Student Achievement 14

2.1 Instructional Tests Developed and Administered by the Participating Teachers, 1961-63 22

2.2 Instructional Tests Developed and Used in 1962-63 24

2.3 Test Scores of the CTMM, Short Form, 1957 Edition, for Students in School 1 and BSCS Students of Teacher A 26

2.4 Test Scores of the CTMM, Short Form, 1957 Edition, for Students in School 1 and BSCS Students of Teacher E 27

2.5 Test Scores of the CTMM, Short Form, 1957 Edition, for Students in School 2 and BSCS Students of Teacher B 28

2.6 Test Scores of the CTMM, Short Form, 1957 Edition, for Students in School 3 and BSCS Students of Teacher C 29

2.7 Test Scores of the Kuhlmann-Anderson Test for Students in School 4 and BSCS Students of Teacher D 31

2.8 Raw Scores of the DAT, Form A, 1959, for Students in School 5 and BSCS Students of Teacher F 32

2.9 Test Scores of the PMA Form AM, and the SCAT, Form 2A, Total Score for Students in School 6 and BSCS Students of Teacher G 34

2.10 Frequency Distribution of Test Group on DAT Form A (Verbal Reasoning + Numerical Ability) by Percentiles . . . 36

2.11 Mid-Point Percentiles on the Combined Verbal Reasoning + Numberical Ability of the DAT, Form A, for Students in the Test Group 39

3.1 Test Analysis Grid for Test 41 45

LIST OF TABLES--continued

Table Page

3.2 Distribution of Correct Scores for Test 41 51

3.3 Item Responses to the Questions on Test 41: Test Group . . 52

3.4 Can-Cannot Analysis of Test 41 56

3.5 Item Responses to the Questions on Test 41: Cans 58

3.6 Item Responses to the Questions on Test 41: Cannots . . . 59

3.7 Test Analysis Grid for Test 42 63

3.8 Distribution of Correct Scores for Test 42 69

3.9 Item Responses to the Questions on Test 42: Test Group . . 70

3.10 Can-Cannot Analysis of Test 42 76

3.11 Item Responses to the Questions on Test 42: Cans 77

3.12 Item Responses to the Questions on Test 42: Cannots . . . 78

3.13 Test Analysis Grid for Test 43 83

3.14 Distribution of Correct Scores for Test 43 91

3.15 Item Responses to the Questions on Test 43: Test Group . . 93

3.16 Item Responses to the Questions on Test 43: Cans 94

3.17 Item Responses to the Questions on Test 43: Cannots . . . 95

3.18 Composition of Test 43 97

3.19 Can-Cannot Analysis of Test 43 104

3.20 Working Paper: The Chemistry of Life 109

3.21 Test Analysis Grid for Test 44 114

3.22 Distribution of Correct Scores for Test 44 126

3.23 Item Responses to the Questions on Test 44: Test Group . 130

3.24 Item Responses to the Questions on Test 44: Cans 132

3.25 Item Responses to the Questions on Test 44: Cannots . . . 134

LIST OF TABLES--continued

Table | Page

3.26 Can-Cannot Analysis of Test 44 142

3.27 Test Analysis Grid for Test 46 147

3.28 Distribution of Correct Scores for Test 46 157

3.29 Item Responses to the Questions on Test 46: Test Group . 160

3.30 Item Responses to the Questions on Test 46: Cans 161

3.31 Item Responses to the Questions on Test 46: Cannots . . . 162

3.32 Can-Cannot Analysis of Test 46 171

3.33 Analysis Form for Selection of Priorities for First Semester Final, 1962-63 174

3.34 Model for Development of Test 48 180

3.35 Distribution of Correct Scores for Test 48 200

3.36 Item Responses to the Questions on Test 48: Test Group . 202

3.37 Item Responses to the Questions on Test 48: Cans 205

3.38 Item Responses to the Questions on Test 48: Cannots . . . 208

3.39 Can-Cannot Analysis of Test 48 213

3.40 Test Analysis Grid for Test 49 228

3.41 Distribution of Correct Scores for Test 49 241

3.42 Item Responses to the Questions on Test 49: Test Group . 244

3.43 Item Responses to the Questions on Test 49: Cans 246

3.44 Item Responses to the Questions on Test 49: Cannots . . . 248

3.45 Achievement of the Test Group, Cans, and Cannots for Five Areas of Emphasis in Test 49 251

3.46 Can-Cannot Analysis of Test 49 252

3.47 Major Areas of Understandings for Year Ending Final . . . 256

3.48 Distribution of Correct Scores for Test 55 276

LIST OF TABLES--continued

Table Page

3.49 Item Responses to the Questions on Test 55: Test Group . 278

3.50 Item Responses to the Questions on Test 55: Cans 280

3.51 Item Responses to the Questions on Test 55: Cannots . . . 282

3.52 Can-Cannot Analysis of Test 55 286

4.1 Readability of the Blue Version of BSCS High School Biology Texts 1961 and 1963 296

4.2 Readability of the Blue Version of BSCS High School Biology Texts 1961 and 1963 298

4.3 Relative Placement of Several High School Biology Texts on the Dale-Chall Readability Score 300

4.4 Rank Order of Density Response to Magazine Reading of 368 Boys and 374 Girls 306

4.5 Rank Order of Density Response to Magazine Reading of 368 Boys and 374 Girls 307

4.6 Density Differences Between Boys and Girls on Science Related Magazines 308

4.7 Density Differences Between Boys and Girls on General News and Pictorial Magazines 309

4.8 Reading Difficulty Levels of Magazines Read by 742 Students 311

5.1 Reliability Coefficients of Eight Instructional Tests . . 316

LIST OF ILLUSTRATIONS

Figure		Page
2.1	Raw Scores for DAT (VR + NA) Required to Obtain a Converted Score at the 50th Percentile on the Publisher's Tables	37
3.1	Frequency Distributions for Students Taking Test 41 by Publisher's Percentile Scores	60
3.2	Frequency Distributions for Students Taking Test 42 by Publisher's Percentile Scores	79
3.3	Frequency Distributions for Students Taking Test 43 by Publisher's Percentile Scores	106
3.4	Frequency Distributions for Students Taking Test 44 by Publisher's Percentile Scores	128
3.5	Percentage of Correct Responses of Three Groups on Questions Assessing Selected Aspects of Protein Chemistry	137
3.6	Percentage of Correct Responses of Three Groups on Questions Assessing Selected Aspects of the ADP-ATP Cycle	138
3.7	Frequency Distribution for Students Taking Test 46 by Publisher's Percentile Scores	158
3.8	Frequency of Correct Responses to a Three Question Series on Mitosis	165
3.9	Frequency Distribution of Responses to a Question Series on DNA	166
3.10	The Distribution of Questions on Test 48	183
3.11	Frequency Distributions for Students Taking Test 48 by Publisher's Percentile Scores	201
3.12	Percentage of Students in the Test Group, Cans, and Cannots Selecting the Best Response to Questions in the Four Areas of Test 48	211

LIST OF ILLUSTRATIONS--continued

Figure Page

3.13 Questions Grouped as Assessing Aspects of the Nature of Theory 218

3.14 Questions Grouped as Assessing Aspects of Interpreting Experiments 220

3.15 Frequency Distributions for Students Taking Test 49 by Publisher's Percentile Scores 242

3.16 The Distribution of Questions on Test 55 259

3.17 Frequency Distributions for Students Taking Test 55 277

5.1 Test Reliability Coefficients plotted in relation to test length, for the eight instructional tests 317

5.2 Mean Achievement of Test Group, Cans, and Cannots for each of the eight instructional tests 320

5.3 Achievement of Test Group, Cans, and Cannots on 42 questions categorized as assessing the "nature of science" from six tests 326

CHAPTER I

BACKGROUND AND DEVELOPMENT OF THE STUDY

Background of the Project

In the summer of 1961 John W. Hole, Jr., Center Leader of the Los Angeles County Biological Sciences Curriculum Study *Blue Version* Test Center,[1] requested the services of the writer in assisting the participating teachers in developing instructional tests. This request was based upon experiences of some members of the Center in using the 1960 edition of the *Blue Version*[2] during the 1960-61 school year which indicated the desirability of developing more effective instructional tests.

The Center participants[3] met weekly to discuss progress and problems as they used the text and laboratory materials. Weekly evaluations from each individual and from the group discussions were forwarded to the Biological Sciences Curriculum Study. Part of each meeting was devoted to discussing the short term objectives of instruction and assisting the writer in preparing tests which the teachers might use for specified areas of instruction. Responses of the students on the tests were supplied to the writer for analysis. Discussion of problems with the test questions, suggestions for questions for inclusion on future tests, and discussion of the central ideas of importance to general education biology for 10th grade students became a regular part of the Center meetings. Sixteen multiple-choice tests, one short essay test, one completion test, and one laboratory practical test were developed for teacher use in 1961-62. From 200 to over 800 students took each of these tests during the school year.

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[1] This Center was a part of the official BSCS *High School Biology Blue Version* trial groups. Eleven such centers were located throughout the United States in 1961-62 to use and evaluate text and laboratory materials produced by the Biological Sciences Curriculum Study. Readers are referred to the *BSCS Newsletter*, especially numbers 6, 8, 12, 17, and 22, for further information about the BSCS project.

[2] The *Blue Version* was one of three versions of text and laboratory materials developed by the BSCS. It was produced in a paperbound edition in 1960, a paperbound revised 1961 edition, and has been subsequently produced in hardbound form as *Biological Sciences, Molecules to Man* (Boston: Houghton Mifflin Company, 1963).

[3] Dr. Dean A. Anderson, Los Angeles State College, Consultant; Mr. R. G. Anderson, San Marino High School; Mrs. Katherine R. Burns, Santa Monica High School; Mr. Michael R. Conti, Pasadena High School; Mrs. Dorothy Glick, John Muir High School; Mr. John W. Hole, Jr., California High School, Center Leader; Mrs. Elizabeth Serbell, Santa Fe High School; Mr. Al Walker, Santa Monica High School. Although not an official participant, Mr. James T. Robinson, Consultant, Office of the Superintendent of Schools of Los Angeles County, participated in the Center meetings as a consultant in evaluation.

The interest of the participating teachers in revising the tests in a second year of study, even though the BSCS Center meetings would no longer be held, led the writer to develop a research proposal for support of such a project so that several research activities could be more specifically developed. Interest was such that the participating teachers agreed to continue the project even without the support of such funds, if necessary, and suggested that other biology teachers be invited to participate in order to expand the group to ten to twelve teachers.

Letters were sent to eleven school superintendents during the summer of 1962 explaining the nature of the project for developing instructional tests[1] and requesting the designation of a biology teacher who might participate. In each case the project director knew that a teacher in the school system had used the BSCS materials in 1961-62 or was planning to use them in 1962-63, and in most instances this teacher was suggested to the superintendent as a potential member of the study group. All participants of the 1961-62 Test Center were included in the invitational group.

---

[1] See Appendix A, pp. 337-356.

Eight district superintendents agreed to participate in the project and to send a total of thirteen teachers. By the opening of school one teacher had withdrawn because of the excessive distance to meetings, and after two meetings two more teachers withdrew since they were not following the developed sequence of instruction. Ten teachers[1] participated throughout the year, nine attending the planning meetings and one participating only by using the tests and supplying data on student achievement.

Organization for the Development of Instructional Tests

A preliminary schedule of nineteen meetings[2] for the development of about ten instructional tests during the school year 1962-63 was sent to the participating teachers. The purposes of the meetings were to plan the objectives of instruction for specific areas of study, to review questions from the 1961-62 tests, and to critique the developed tests after use in the classroom.

---

[1] Mr. Michael A. Conti, Pasadena High School; Mrs. Dorothy Glick, John Muir High School; Mrs. Marit Goldsworthy, West Covina High School; Mr. John W. Hole, Jr., California High School; Mr. Kenton Horner, West Covina High School; Mr. Donald Jenkins, Santa Fe High School; Mr. Gordon Peterson, San Marino High School; Mrs. Elizabeth Serbell, Santa Fe High School; Mr. Carl Torkko, Morningside High School; Mr. Al Walker, Santa Monica High School.

[2] See Appendix A, pp. 341-43.

The initial proposal of developing about ten instructional tests for the year was modified to a more flexible proposal of developing a test for specified areas of study as the year progressed. Guidelines for the development of these tests were as follows:

1. Specification of the area of instruction to be included in the instructional test.

2. Development of the major ideas and areas of emphasis within the specified area of instruction.

3. Each test was to be considered as a "core" test of those aspects of the objectives of instruction which could be agreed upon by all the participants. A "core" test was defined as a test over ideas which were considered basic regardless of the particular approach of a teacher. Each teacher would add questions as he wished to test additional aspects of instruction.

4. Each test would include from 10 to 25 multiple-choice questions and would be provided in mimeographed copy in class sets of 40 copies for each teacher.

5. Each test would include a "range" of content harmonious with the development of ideas in the text and laboratory guide. The development of the cognitive range in the questions was aided by use of the Taxonomy of Educational Objectives,[1] and each question was categorized by the project director in accordance with the

---

[1] The Classification of Educational Goals, Handbook 1: Cognitive Domain, Benjamin S. Bloom, (ed.) (New York: David McKay Company, Inc., 1956).

Taxonomy. In this way the instructional tests would be designed, where possible, to assess understandings beyond recall.

6. Each test developed in the study would be considered available for use by the participating teachers; but should any teacher consider that the use of any particular test would be inappropriate for his use, there would be no obligation to use it.

Research Design

This study was designed to provide a framework within which teachers could work cooperatively to develop specific goals of instruction and then to consider approaches to evaluation which might assess various levels of understanding attained by students. The study offered a unique opportunity to consider several pertinent variables in the instructional context and to increase the description of the range of data which might influence student achievement. This uniqueness was ascribed to the fact that the teachers in the study would meet regularly, as most of them had in the previous year, discuss difficulties which they had with the text and with laboratory exercises, decide what aspects of instruction should be emphasized, discuss some of the problems of instruction for the particular student group with whom they were working, and plan measures of evaluation. Most of the teachers had participated in the previous year's work of developing instructional tests and these tests which had been previously used were available as resource materials for revision and for use in the development of new tests for the 1962-63 school year. In the design of the study the following hypotheses were proposed:

1. Are the most difficult questions answered correctly by students with such common characteristics as verbal reasoning, numerical aptitude, etc.?

2. Do students who achieve scores falling within the approximate upper quartile of the objective test questions score within the same range on laboratory performance tests in the same area; for example, use of the microscope, technique of measurement, etc.?

Do students who achieve scores falling within the approximate lower quartile of the objective test have scores within the same range on the laboratory performance test?

3. How do selected students perform on test items concerned with general themes, such as the nature of hypothesis, etc., at given intervals throughout the year?

4. Do students with different academic aptitudes achieve differently if they are in contrasting types of classes? For example, what can be discovered about the achievement of the students with low academic aptitudes in a class made up predominantly of students with high academic aptitude; or what can be discovered about the achievement of students with high academic aptitudes who are in

a class composed generally of students with lower academic aptitude than their own?

5. Do tests with different patterns--i.e., all recall questions, all application questions, a range of questions, etc.--provide differential discrimination as to those students who are high, low, or middle achievers?

Specifically, the project sought to determine within the limitations of an action research context the science understandings of biology students as determined by the developed instructional tests.

The tables which follow present the specific research design and methodology.

TABLE 1.1

The Student Population

Problems to be Investigated	Data Gathered
1. What are some selected characteristics of the students in the test group?	1. Responses to a "Biology Questionaire."[1]
2. How do test group students compare with their classmates on available standardized test scores?	2. Intelligence or aptitude test scores from school records of students in the test group. Intelligence or aptitude test scores from school records of students at the same grade level(s) as students in the test group.
3. Why do different achievement patterns appear between classes within a school? Do these differentials hold if matched groups from these classes are compared?	3. All data collected in this study were organized by class group for each teacher.

[1] See Appendix B, pp. 358-59.

Methods of Analysis	Areas for Further Study
1. Tabulations of responses to questions by boys by girls by all students in the test group.[1]	1. Analyze differential patterns of responses to these questions for each teacher and correlate these analyses with achievement on the instructional tests.
2. Computation of means and standard deviations for each group.	
3. Analysis of all data using the class groups as a base was attempted. Transfer of students among classes and the lack of data on entrance and withdrawal of students made the boundaries of class groups undefined.	3. Keep dated records of entrance and withdrawal of students beginning with the first day of class with anecdotal record of reasons for entrance and withdrawal so that boundaries of a class group may be operationally defined.

---

[1] See pp. 305-12.

TABLE 1.2

The Instructional Materials

Problems to be Investigated	Data Gathered
1. What assessments can be made regarding the readability of the text and laboratory materials?	1. Selection of a 10% random sample from the 761 pages of the text. Tabulations of sentence length, number of syllables per 100 words, number of prepositional phrases per 100 words, listing the words not on Dale's list of "769 Easy Words," and marking words listed which were not on Dale's "3,000 Familiar Words" list.

Methods of Analysis	Areas for Further Study
1. Computation of the Flesch Reading Ease Score (1948) and the Dale-Chall Readability Score (1948) for the selected passages.[1]	1. Investigate the levels of conceptualization, rate of build-up of complexity of ideas, and the frequency of introduction[2] of scientific terms.

[1] See Chap. 2.

[2] See pp. 301-02.

TABLE 1.3

The Instructional Tests

Problems to be Investigated	Data Gathered
1. Do the instructional tests assess those aspects of understanding which are consistent with the themes and objectives of instruction?	1. The questions developed, the BSCS themes and objectives, and instructional objectives developed for each test.
2. What are the characteristics of the tests as determined by the Taxonomy?	2. The questions as used in the study.
3. What are the characteristics of the tests and test items regarding a. reliability b. discrimination c. difficulty	3. Total correct scores for each student and item responses for each student.

Methods of Analysis	Areas for Further Study
1. Schemata of test composition, content by grids using the *Taxonomy*, and the relation of test patterns to major ideas are presented.	1. Develop and validate additional questions to assess instructional areas where the number of questions was limited.
2. Assignment by the project director of a *Taxonomy* category for each question.[1]	2. Encourage evaluation of assigned *Taxonomy* category by other investigators.
3. Statistical methods a. Kuder-Richardson Reliability Formula 20 b. Can-Cannot analysis and biserial correlation c. Number of students marking the responses correctly as a proportion of the number of students taking the test	

---

[1] See Chap. 3.

TABLE 1.4

Student Achievement

Problems to be Investigated	Data Gathered
1. What is the relative achievement of each class?	1. Total correct scores for each class of each teacher.
2. What was the achievement of the total test group on each instructional test? a. Achievement on each item of each test. b. Achievement on clusters of questions grouped to assess specific instructional objectives for each test.	2. a. Total correct scores for the test group for each test, and total correct scores for each question of each test. b. The instructional objectives for each test and the questions proposed for assessing these objectives.
3. What was the relative achievement of the "Can" and "Cannot" groups on each instructional test? a. Achievement on all items of each test. b. Achievement of clusters of questions grouped to assess specific instructional objectives for each test.	3. Item response frequencies for the total test group, the "Cans," and "Cannots."[1]

---

[1] See Chap. 3.

Methods of Analysis	Areas for Further Study
1. Computation of means and standard deviations of correct scores by class groups. This did not prove feasible as boundaries of classes remained undefined.[1]	1. See Table 1.1, number 3, page 9 above.
2. a. Computation of means and standard deviations for each test. b. Preparation of content analysis schemata of the test in relation to instructional objectives and computation of the relative success of students for the questions designed to assess these objectives.	
3. a. Computation of ratio of "Can" to "Cannot" correct responses. b. Determination of biserial correlation for each question by using Flanagan tables.[2] c. Computation of correct response pattern of "Can" and "Cannot" groups for questions developed in "2.b" above.	3. Conduct further investigations of the relations of the assumptions underlying the biserial correlation to instructional test development.

[1] *Supra*, p. 9.

[2] See Chap. 3.

Statistical Procedures

The standard deviations and variances of each instructional test were calculated by a computer program by determining $L_x + N\Sigma X^2 - (\Sigma X)^2$, computing the variance $s_x^2 = L_x/N^2$, and computing the standard deviation (s_x) as the square root of s_x^2. The output data from this program also included the mean ($\bar{x}$), Σx, Σx^2, and L_x. These output data provide part of the data for use in other statistical analyses used in this study.

All tests were scored on the basis of one correct answer per question by a test scoring program which produced output cards for each student for all tests taken by that student. Output cards of raw scores for each student and the Fast Answer Cards[1] of each student served as the input source for all of the basic statistical work.

Item Analysis

An item analysis for each instructional test was accomplished by a program for the RCA 301 computer. Item frequencies for the test group and various sub-groups were secured from that program. Output of this program consisted of frequencies and percentages of students on each available choice for each question.

Test Reliability

Test reliability was assessed by applying a formula equivalent to the Kuder-Richardson Formula 20 (1939) which is based on the assumption that the average variance between non-parallel items is equal to the average covariance between parallel items.[2] If the assumption is invalid, the resulting coefficient will be lower than if the assumption is valid and thus the calculated reliability coefficient is a lower bound for the reliability coefficient of each test.[1]

---

[1] See Appendix B, p. 360.

[2] Harold Gulliksen, Theory of Mental Tests (New York: John Wiley & Sons, Inc., 1950), p. 224.

Test Validity

The validity of the tests which concerned the project director and the teacher participants may be referred to as "educational" or "instructional" validity. In order to establish the "instructional validity" the relationship between each test question and the immediate objective of instruction which each question was designed to assess and the relationship of these objectives to the objectives for the year course in biology were developed by the participants in cooperation with the project director. Thus, instructional validity rests on the combined judgments, training, and experience of these individuals.

Can-Cannot Analysis

A Can-Cannot analysis was developed for each test in terms of achievement on that test. Cans were selected as the highest 27 percent of the students in total correct raw score points on each test. Cannots were selected as the lowest 27 percent of the students in total correct raw score points on each test.[2] The Can-Cannot data were used to evaluate the direction and degree of discrimination of each item. The degree of discrimination is presented as a ratio of correct responses of Cans to Cannots and the direction of discrimination is termed positive when the proportion of Cans selecting the best response was greater than the proportion of the Cannots; negative when more Cannots than Cans selected the best response.

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[1] Loc. cit.

[2] Jack C. Merwin, "Constructing Achievement Test and Interpreting Scores," The National Council of Teachers of Mathematics, Evaluation in Mathematics (26th Yr. Book, Washington, D.C., 1961), pp. 61-66.

Correlation

A correlation coefficient (PBIS) for each question was determined by the method developed by Flanagan.[1] The proportion of the Can and Cannot groups answering each question correctly is used in this procedure. Where the number needed to make an exact 27 percent of N fell at a single raw score point, all the students achieving a correct score at that level were given numbers and a table of random numbers was used to select from this pool the number necessary to include 27 percent in both upper and lower groups. The method of Flanagan was two tails of the distribution and even though one variable is dichotomous and the other continuous, the dichotomized trait is assumed to be actually continuous. The coefficient calculated by this method is an estimate of the correlation coefficient in a bivariate normal population and is considered a close estimate of a biserial correlation.[2] Although frequently used in studies similar to this one, the suitability of this correlation coefficient will be discussed in the findings of this study.

Interpretation of the coefficient in this report will follow Diederich who states

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[1] Helen M. Walker and Joseph Lev, Statistical Inference (New York: Henry Holt and Company, 1953), pp. 275-276.

[2] *Loc. cit.*

> The professionals like to have their average biserial above .4 and are quite proud of themselves if it hits .5 or above. They look hard at items with biserials below .3 and either touch them up or get rid of them unless they can prove on other grounds that the item is a good item that is not closely related to the rest of the test.[1]

A search of a number of texts on statistics provided no further clarification for interpretation.

Data Processing

Processing of the data gathered in the study was done on the RCA 301 computer operated by the Statistical Section, Division of Research and Guidance, Office of the Superintendent, Los Angeles County Schools. The data from Tests 41 and 42 were gathered on mimeographed answer sheets and the item responses for each student were key punched. The remaining tests were marked by students on Fast Answer Cards. Mark sensing of the Fast Answer Cards was done on IBM 514 equipment.

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[1] Paul B. Diederich, Short-Cut Statistics for Teacher-Made Tests (Evaluation and Advising Service Series No. 5; Princeton, N. J.: Educational Testing Service, 1960), p. 5.

CHAPTER II

PRESENTATION AND ANALYSIS OF BACKGROUND DATA ON THE STUDENT POPULATION AND THE TEXTBOOK

The Selection of Data for Analysis

During the 1962-63 school year sixteen instructional tests were developed as a part of this study and were available for use by the participating teachers. In addition, some teachers chose to use Tests 01 and 12 from the 1961-62 test series. Tests over the objectives assessed by tests 01 and 12 were not developed in 1962-63 because of change of emphasis or agreement that these two tests were satisfactory in an unrevised form. Test numbers, titles, number of questions, and the sequence of instruction for which the tests were designed are presented in Table 2.1.

Master class lists of students for each teacher were prepared at the beginning of the year. A "Biology Questionaire"[1] filled out by each student was the basis for the original compilation of the master class list. Differential Aptitude Tests (DAT) for Verbal Reasoning and Numerical Ability were administered during the first or second week of school to all students enrolled in the classes at that time. Additional students were added to the master class list throughout the school year.

Those students who had filled out a questionaire or who had taken the DAT test but for whom no instructional test scores in biology were

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[1] See Appendix B, pp. 358-59.

TABLE 2.1

Instructional Tests Developed and Administered[1] by The Participating Teachers, 1962-63, Listed in Order of Development and Use

	Test No.	Part[2] No.	Test Title	No. of Questions	
				Part[2]	Total
FIRST SEMESTER	41		The Nature of Science		10
	01		The Microscope		10
	42		Classification		12
	43		Changes in Living Things		20
	44	1	The Chemical Basis of Biology	25	
	44	3	Movement of Substances	10	35
	45		The Heterotroph Hypothesis		15
	46	1	The Cell	15	
	46	3	Photosynthesis	10	25
	12		Reproduction		20
	47		Semester I Final Lab Practical		20
	48	1	Semester I Final Examination	25	
	48	2	Semester I Final Examination	25	
	48	3	Semester I Final Examination	15	65
SECOND SEMESTER	49	1	Genetics	25	
	49	3	Genetics	15	40
	50		Population Genetics		20
	51	1	Transport in Animals	20	
	51	5	Transport in Animals	35	55
	52		Digestion and Excretion		25
	53	1	Integration in Animals	25	
	53	3	Integration in Animals	10	35
	54		Integration in Plants and Animals		25
	55	1	Semester II Final Examination	25	
	55	3	Semester II Final Examination	25	50

[1] Tests 01 and 12 were developed and used unrevised.

[2] Some tests were developed in parts due to the subject or to the form of the answer card.

secured were dropped from inclusion in the data of the study. With these students eliminated, the master class lists form the basis for the total group of students to be reported. Since students may have missed one or more instructional tests during the course of the year, any student taking at least one instructional test was retained in the study. DAT scores, Biology Questionaires, and district administered standardized test scores were secured for each student when this was possible.

Since the use of instructional tests was optional,[1] use patterns among the teachers varied and a selection of data for the purposes of this study was necessary in order to secure the maximum number of tests given by the maximum number of teachers. The complete pattern of test use with the number of students tested on each instrument is presented in Table 2.2 The data in the shaded area are not being processed for this report but will be analyzed as this becomes possible.

Data from Teacher "I" were eliminated from the study because standardized test scores and DAT scores were not provided. Data from the second semester final examination (Test 55) were not secured from Teachers "H" or "J" so their data were eliminated from this study. For the seven remaining teachers tests were eliminated if any one teacher did not provide the results of a test. The resultant core of data includes eight tests given by seven teachers. The students for each of these tests will be referred to as the "Test Group." The exact student composition for any one test may differ from that on another test due to absence, transfer students, etc.

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[1] *Supra*, p. 5

TABLE 2.2

Instructional Tests Developed and Used in 1962-63*
Data in the Shaded Area Are Not Included
As a Part of This Study**

Test No.	NUMBER OF STUDENTS TESTED BY EACH TEACHER											N Test Group
	"A"	"B"	"C"	"D"	"E"	"F"	"G"	"H"	"I"	"J"	N All Students	
41	47	149	92	100	32	136	104	105	32	..	797	660
01	..	120	82	..	..	..	107	..	..	..	309	-
42	47	149	90	100	32	135	107	115	31	..	806	660
43	46	151	81	97	63	137	109	110	32	..	826	684
44	41	150	91	99	60	132	106	..	27	17	723	679
45	42	149	..	95	63	129	105	..	23	..	606	-
46	44	148	89	95	63	130	104	..	29	18	720	673
47	..	145	82	85	..	132	..	103	..	..	547	-
48	44	144	89	95	63	132	110	99	27	20	823	677
12	48	146	89	93	60	..	104	..	27	..	567	-
49	45	137	84	95	59	125	107	103	26	..	781	652
50	44	138	..	93	63	..	106	..	..	..	444	-
51	45	138	82	..	59	129	105	93	25	15	691	-
56***	45	137	81	..	59	127	..	92	22	..	563	-
52	41	138	82	96	..	..	105	98	30	..	500	-
53	46	137	81	..	61	..	107	..	29	..	461	-
54	46	137	82	96	60	..	..	..	18	..	439	-
55	45	136	82	95	62	129	107	..	28	..	684	656
Number of Tests Used	16	18	16	14	15	12	15	9	15	4		8

*Tests 01 and 12 were developed in 1961-62 and were used unrevised.

**See pp. 21-23 for an explanation of teacher and test selection.

***Test 56 was a separate completion type test which was an optional supplement to Test 51.

The Student Population

The student population whose instructional test achievement is reported in this study is considered from three aspects. The first aspect will describe the students in the test group in comparison with students at the same grade level within each school. The data for this part of the study were obtained directly from the school district or were secured with permission of the school district from the Statistical Section, Division of Research and Guidance. Since the standardized tests used by the schools participating in the study differed, the development of summary data from these sources could not be accomplished. Second, the school population will be described from the DAT scores, and, third, through the responses from the Biology Questionaire.[1]

School Standardized Test Data

School 1

This is a four year high school with grades 9-12. No science is required of any student for graduation, but college preparatory students are advised to take two or three years of science. Life Science is offered as a general education course, and Biology is offered as a college preparatory laboratory science for 11th and 12th grade students. All six sections of Biology, enrolling approximately 160 students, used BSCS materials[2] during 1962-63. Two teachers taught the BSCS sections.

Teacher A taught two BSCS Biology sections. A comparison of the students of Teacher A and the students in School 1 on the basis of total IQ scores as measured by the California Test of Mental Maturity[1] is shown in Table 2.3.

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[1] See Appendix B, pp. 358-59.

[2] This and all further references in this report to BSCS materials will refer to the Blue Version, 1961 edition, materials

TABLE 2.3

Test Scores of the CTMM, Short Form, 1957 Edition, for Students in School 1 and BSCS Students of Teacher A

<table>
<tr><th colspan="7">IQ SCORES FROM CTMM, SHORT FORM 1957</th></tr>
<tr><th colspan="7">Students, School 1</th></tr>
<tr><th>Grade</th><th>N in Grade</th><th>N in Grade Tested</th><th>% in Grade Tested*</th><th>$\bar{X}$</th><th>s</th><th>s^2</th></tr>
<tr><td>10</td><td>?</td><td>0</td><td>0</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>11</td><td>?</td><td>725</td><td>0</td><td>105.1</td><td>11.9</td><td>142.3</td></tr>
<tr><td>12</td><td>?</td><td>0</td><td>0</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>TOTAL</td><td>?</td><td>725</td><td>0</td><td>105.1</td><td>11.9</td><td>142.3</td></tr>
<tr><th colspan="7">BSCS Students, Teacher A</th></tr>
<tr><th></th><th>N in Grade</th><th>N in Grade Tested</th><th>% in Grade Tested*</th><th>$\bar{X}$</th><th>s</th><th>s^2</th></tr>
<tr><td>10</td><td>1</td><td>0</td><td>0</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>11</td><td>17</td><td>12</td><td>70.5</td><td>106.9</td><td>8.7</td><td>75.2</td></tr>
<tr><td>12</td><td>34</td><td>0</td><td>0</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>TOTAL</td><td>52</td><td>12</td><td>23.1%</td><td>106.9</td><td>8.7</td><td>75.2</td></tr>
</table>

*In Tables 2.3 to 2.8, "% of Grade Tested" refers to those students tested during the school year 1962-63.

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[1] Short Form, 1957 Edition, California Test Bureau, Monterey, California. All following references will refer to this test as the CTMM.

Teacher E taught four sections of BSCS Biology, two of which were used in this study. The two sections not used were designated as Biology 1A-2A classes with students selected for above average ability, by teacher recommendation, and with parental approval.

A comparison of the students of Teacher E and the students in School 1 on the basis of total IQ scores as measured by the CTMM is shown in Table 2.4.

TABLE 2.4

Test Scores of the CTMM, Short Form, 1957 Edition, for Students in School 1 and BSCS Students of Teacher E

IQ SCORES FROM CTMM, SHORT FORM 1957						
Students, School 1						
Grade	N in Grade	N in Grade Tested	% in Grade Tested	$\bar{X}$	s	s^2
11	?	725	0	105.1	11.9	142.3
12	?	0	0	-	-	-
TOTAL	?	725	0	105.1	11.9	142.3
BSCS Students, Teacher E						
Grade	N in Grade	N in Grade Tested	% in Grade Tested	$\bar{X}$	s	s^2
11	26	25	36.8	104.6	6.9	47.5
12	42	0	0	-	-	-
TOTAL	68	25	36.8	104.6	6.9	47.5

School 2

This is a senior high school with grades 10, 11, and 12. All students are required to take one year of science and must elect a second year of science, mathematics, or foreign language in grades 9-12. Twenty-two sections of Biology were sceduled for 1962-63, enrolling approximately 600 students. Students enrolled in Biology were grouped for instruction on the basis of ability and educational goals. The five BSCS sections taught by Teacher B were "college preparatory" groups including the more able students of the 10th grade class.

A comparison of the students of Teacher B and the students in School 2 based upon the total IQ score as measured by the CTMM is shown in Table 2.5.

TABLE 2.5

Test Scores of the CTMM, Short Form, 1957 Edition, for Students in School 2 and BSCS Students of Teacher B

IQ SCORES FROM CTMM, SHORT FORM, 1957						
Students, School 2						
Grade	N in Grade	N in Grade Tested	% in Grade Tested	$\bar{X}$	s	s^2
10	1016	922	89.3	107.0	14.6	215.4
11	?	0	0	-	-	-
12	?	0	0	-	-	-
TOTAL	1016	922	89.3%	107.0	14.6	215.4
BSCS Students, Teacher B						
Grade	N in Grade	N in Grade Tested	% in Grade Tested	$\bar{X}$	s	s^2
10	156	141	79.3	117.8	12.8	164.9
11	8	0	0	-	-	-
12	1	0	0	-	-	-
TOTAL	165	141	79.3%	117.8	12.8	164.9

School 3

This is a four year high school with grades 9-12. All students are required to take one year of science in grades 10, 11, or 12. Life Science is offered as a 10th grade elective for fulfilling the science requirements for graduation, but it does not satisfy the college preparatory laboratory science requirement. Advanced Biology is offered at the 11th and 12th grades as a college preparatory laboratory science. No previous science is required for enrollment. All three Advanced Biology classes for 1962-63 were taught by Teacher C and used the BSCS materials. Ninety-four students were taught by Teacher C in these classes.

A comparison of the students of Teacher C and the students in School 3 based upon the total IQ scores as measured by the CTMM is shown in Table 2.6.

TABLE 2.6

Test Scores of the CTMM, Short Form, 1957 Edition, for Students in School 3 and BSCS Students of Teacher C

IQ SCORES FROM CTMM, SHORT FORM, 1957						
Students, School 3						
Grade	N in Grade	N in Grade Tested	% in Grade Tested	$\bar{X}$	s	s^2
11	?	476	0	103.4	12.1	144.2
12	?	0	0	-	-	-
TOTAL	?	476	0	103.4	12.1	144.2
BSCS Students, Teacher C						
Grade	N in Grade	N in Grade Tested	% in Grade Tested	$\bar{X}$	s	s^2
11	46	43	45.8	106.4	12.6	159.2
12	48	0	0	-	-	-
TOTAL	94	43	45.8%	106.4	12.6	159.2

School 4

This is a senior high school with grades 10, 11, and 12. All students are required to take Biology and one other science for graduation. Biology is usually taken at the 10th grade level but is not designed to fulfill the laboratory science requirement for college entrance. Students may take Biology in summer school to fulfill this requirement and many do. The four sections of Biology using the BSCS materials for 1962-63 were selected from all the students who registered for Biology and were all taught by Teacher D. These sections were listed in the "October Report of High Schools, 1962,"[1] as a part of the school's program for the more able student.

A comparison of the students of Teacher D with the total student group at School 4 (Table 2.7) indicates the relative abilities of these students as measured by the Kuhlmann-Anderson Intelligence Test,[2] Total Score. Eighteen sections of Biology were scheduled for the year, enrolling approximately 590 students. Students were selected for the BSCS sections on the basis of interest, past performance, selected achievement tests, and IQ scores.[3]

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[1] Part VI--"Administration and Curriculum Practices." Report to the Superintendent of Public Instruction, California State Department of Education, October 31, 1962, p. 10.

[2] Sixth Edition, 1952, Personnel Press, Inc., Princeton, New Jersey.

[3] October Report of High Schools, 1962. Loc. cit.

TABLE 2.7

Test Scores of the Kuhlmann-Anderson Test for Students In School 4 and BSCS Students of Teacher D

KUHLMANN-ANDERSON INTELLIGENCE TEST DATA

Students, School 4

Grade	N in Grade	N in Grade Tested	% in Grade Tested	$\bar{X}$	s	s^2
10	1027*	950	90.2	110.1	16.4	268.0
11	?	0	0	-	-	-
12	?	0	0	-	-	-
TOTAL	1027	950	90.2%	110.1	16.4	268.0

BSCS Students, Teacher D

Grade	N in Grade	N in Grade Tested	% in Grade Tested	$\bar{X}$	s	s^2
10	91	76	83.5	126.4	10.9	118.9
11	5	0	0	-	-	-
12	10	0	0	-	-	-
TOTAL	106	76	71.8%	126.4	10.9	118.9

*Approximate number of students in 10th grade based upon the number of incomplete test scores listed added to the number tested.

School 5

This is a four year high school with grades 9-12. All the students are required to take one year of science in grades 10, 11, or 12. Life Science is offered as a 10th grade elective for fulfilling the science requirement for graduation but does not satisfy the college preparatory laboratory science requirement. Twenty sections of Life Science, enrolling approximately 500 students, were scheduled for 1962-63. Teacher F taught five of these sections using BSCS materials. Students for these five classes were selected as being in the upper 25 percent of the enrollment group primarily on the basis that their reading test scores were one to two years above grade level.[1]

The following comparison of the students of Teacher F and the students in School 5 is based upon the combined Verbal Reasoning and Numerical Ability raw scores of the *Differential Aptitude Test, Form A*.[2]

TABLE 2.8

Raw Scores of the DAT, Form A, 1959, for Students
In School 5 and BSCS Students of Teacher F

RAW SCORES, DAT Verbal Reasoning & Numerical Ability						
Grade	N in Grade	N in Grade Tested	% in Grade Tested	$\bar{X}$	s	s^2
9	?	0	0	-	-	-
10	?	582	0	31.0	16.6	277.1
11	?	0	0	-	-	-
TOTAL	?	582	0	31.0	16.6	277.1
BSCS Students, Teacher F						
Grade	N in Grade	N in Grade Tested	% in Grade Tested	$\bar{X}$	s	s^2
9	1	0	0	-	-	-
10	131	104	79.2	35.8	16.4	269.0
11	11	0	0	-	-	-
TOTAL	143	104	72.8%	35.8	16.4	269.0

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[1] *Loc. cit.*

[2] The Psychological Corporation, New York 17, N. Y., 1959. Further references will refer to this test as the DAT.

School 6

This is a four year high school with grades 9-12. One year of science is required of all students for graduation. Biology is offered as a college preparatory laboratory science for grades 11 and 12, but able 10th graders are admitted to the course. One section of Basic Biology and ten sections of Biology were scheduled for the year with approximately 250 students enrolled. Five sections of Biology used the BSCS materials during 1962-63. These sections were all taught by Teacher G. One of the five sections was composed of a selected group of able 10th graders, and a special course title of Biology AA was given to this section.

A comparison of the students of Teacher G's sections with the total student groups at School 6 is shown in Table 2.9. Securing standardized test data for these students posed difficult problems due to the inclusion of 10th, 11th, and 12th graders in the BSCS classes and the pattern of standardized testing in the school. The School and College Ability Test[1] was given to the 11th grade class in 1962. Scores for the 10th graders were obtained from their 9th grade, 1961, Primary Mental Abilities[2] test data and for the 12th graders from their 11th grade, 1961, PMA test data.

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[1] Educational Testing Service, Princeton, N. J. Subsequent referral will list this test as the SCAT.

[2] Science Research Associates, Chicago, Ill. Subsequent referral will list this test as the PMA.

TABLE 2.9

Test Scores of the PMA Form AM, and the SCAT, Form 2A, Total Score For Students in School 6 and BSCS Students of Teacher G

Students, School 6

Grade 1961	Grade 1962	Test	N* in Grade	N in Grade Tested	% in Grade Tested	$\bar{X}$	s	s^2
9	10	PMA	281	278	99.9	120.1**	17.8	317.8
11	12	PMA	318	301	94.5	116.8**	15.6	243.4
9 + 11		PMA	599	579	96.5	118.4**	16.8	281.8
	11	SCAT	319	316	99.1	300.9***	12.1	145.5
TOTAL			918	895	97.2%	-	-	-

BSCS Students, Teacher G

Grade 1962	Test	N in Grade	N in Grade Tested	% in Grade Tested	$\bar{X}$	s	s^2
10	PMA	43	39	90.8	132.0**	12.3	150.8
12	PMA	9	9	100.0	122.9**	8.6	74.8
10 + 12	PMA	52	51	98.1	128.6**	19.1	366.3
11	SCAT	64	64	100.0	301.5***	10.0	100.5
TOTAL		116	115	99.9%	-	-	-

*N is based on class enrollment of the year of the test data.

**IQ scores of PMA total.

***Converted scores of SCAT.

Differential Aptitude Test Data

The Verbal Reasoning and Numerical Ability sub-tests of the Differential Aptitude Test, Form A, 3rd Edition,[1] were administered to all students participating in the official BSCS evaluation study during the first or second week of school. Permission to use the raw scores from these tests was granted by the BSCS.[2] Frequency distributions of the combined Verbal Reasoning and Numerical Ability (VR + NA) scores are presented in Table 2.10. A total of 744 students make up the Test Group for this study and scores for 88 percent (657) of the students were obtained. Raw scores were converted to percentile scores by a computer program using the publisher's conversion tables.

The mean score for the students tested was 52.7 raw score points. This score converts from a high percentile score of 80 for 10th grade girls to a low percentile score of 50 for 12th grade boys.[3] The 657 students tested included 55 percent 10th graders, 24 percent 11th graders, and 21 percent 12th graders. Boys and girls are almost equally represented in the group tested with 49 percent boys and 51 percent girls. Conversion from raw scores to percentile scores cannot be made except by using the conversion tables which are entered by sex and grade level. It may be safely stated, however, that the students tested represent a more able group than the average. Interpretations of the

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[1] The Psychological Corporation, New York, 1959.

[2] Personal correspondence from Arnold Grobman, Director, Biological Sciences Curriculum Study.

[3] "Directions for Administering and Scoring, 3rd Edition, Differential Aptitude Tests" (New York: The Psychological Corporation, 1959), pp. 27-29.

TABLE 2.10

Frequency Distribution of Test Group on DAT
FORM A (Verbal Reasoning + Numerical Ability) by Percentiles

DAT (VR + NA) Percentiles	BOYS		GIRLS		TOTAL	
	Frequency	Per-centage	Frequency	Per-centage	Frequency	Per-centage
90 - 99	110	29.6	113	30.1	223	30.9
80 - 89	39	10.5	46	12.3	85	11.4
70 - 79	37	10.0	35	9.3	72	9.7
60 - 69	32	8.6	36	9.6	68	9.1
50 - 59	27	7.3	26	6.9	53	7.1
40 - 49	25	6.7	20	5.3	45	6.0
30 - 39	18	4.9	16	4.3	34	4.6
20 - 29	6	1.6	9	2.4	15	2.0
10 - 19	19	5.1	17	4.5	36	4.8
1 - 9	14	3.8	12	3.2	26	3.5
No Score	42	11.8	45	12.0	87	11.6
TOTALS	369	99.9	375	99.9	744	100.7

instructional test results take place within the limitations of generality imposed by the abilities of the students tested. For the purposes of this study abilities were assessed through the DAT (VR + NA) scores.

An examination of the DAT (VR + NA) conversion tables shows that beginning with grade 10, boys must achieve higher raw scores for equivalent percentile scores than girls as is shown in Figure 2.1.

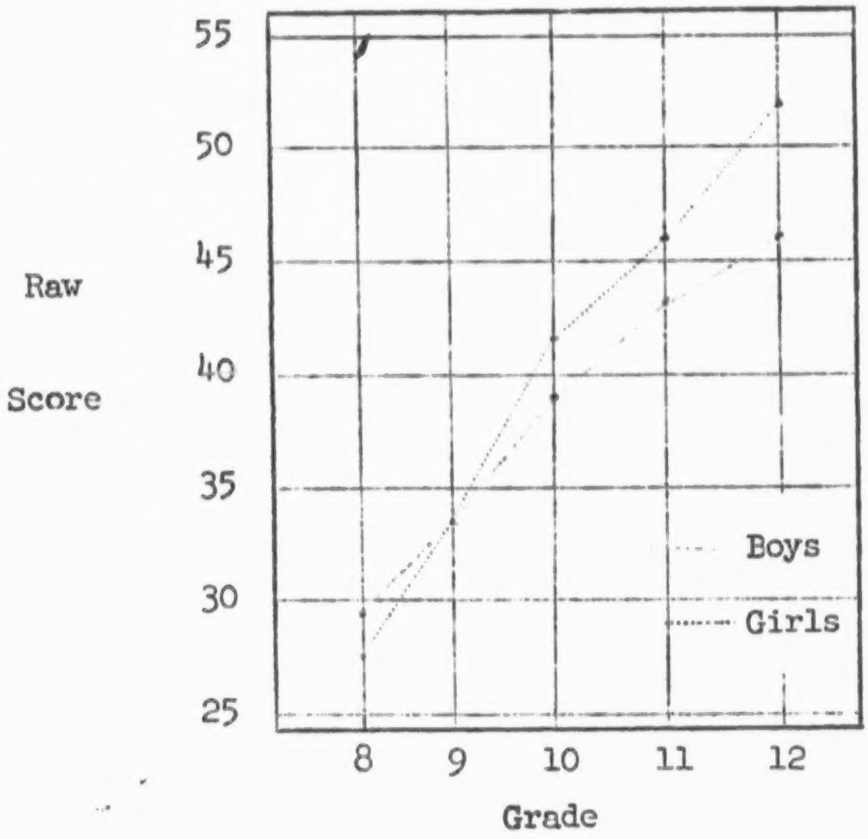

FIG. 2.1. Raw Scores for DAT (VR + NA) Required to Obtain a Converted Score at the 50th Percentile on the Publisher's Tables.[1]

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[1] *Loc. cit.*

Such a differential of raw score performance to percentile scores would not seem appropriate for the interpretation of the instructional tests developed in this study; for the following assumptions seem justifiable:

1. Within a given course, i.e., Biology, Advanced Biology, etc., teachers expect the same performance of both boys and girls.
2. Within a given course and with students of different grade levels within the course, teachers expect the same performance of students regardless of their grade level if they are to be recognized as making equivalent achievement.

Thus a conversion of raw scores irrespective of sex or grade would offer a means of viewing the students tested as a unit. Such a conversion is shown in Table 2.11 which presents a frequency distribution of the 657 students by computed mid-point percentile scores.

TABLE 2.11

Mid-Point Percentiles on the Combined Verbal Reasoning + Numerical Ability of the DAT, Form A, for Students in the Test Group

DAT (VR + NA) Percentiles	BOYS		GIRLS		TOTAL	
	Frequency	Per-centage	Frequency	Per-centage	Frequency	Per-centage
90 - 99	40	10.8	47	12.6	87	11.7
80 - 89	37	10.0	25	6.7	62	8.3
70 - 79	31	8.4	37	9.9	68	9.1
60 - 69	34	9.2	38	10.2	72	9.7
50 - 59	25	6.8	23	6.1	48	6.4
40 - 49	33	8.9	41	10.9	74	9.9
30 - 39	34	9.2	32	8.5	66	8.9
20 - 29	34	9.2	33	8.8	67	9.0
10 - 19	31	0.4	32	8.5	63	8.5
1 - 9	28	7.6	22	5.9	50	6.7
Total Tested	327	88.5	330	88.0	657	88.2
No Scores	42	11.4	45	12.0	87	11.7
Total Test Group	369	99.9	375	100.0	744	99.9

CHAPTER III

THE INSTRUCTIONAL TESTS

Test 41, The Nature of Science

Development of the Test

Test 41 was developed from a series of nineteen questions which had been provided for teachers during the work of the 1961-62 Los Angeles County BSCS Blue Version Test Center. These questions were developed for use by the teachers in building their own tests. Results of the success of students on these questions in 1961-62 were distributed[1] and served as a basis for developing a test on the "nature of science" which would follow the study of chapter 1 in the text and the associated laboratory exercises. This chapter used detective work as an analogy to assist students in understanding the nature of science; presented ideas associated with facts, assumptions, and hypotheses; and sought to develop these ideas in an appropriate context. Coordinated laboratory work is used as the main way for students to gain direct experience in developing an understanding of the nature of science as described in the text.

The teacher participants discussed the central ideas which they wished to develop in this laboratory study and which they hoped the students would begin to understand--ideas which would be emphasized throughout the school year. The objectives for instruction became:

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[1] Robinson, James T., "Some Aspects of Broadening the Bases of Evaluation in Biology." Working papers prepared for the Math-Science Weekend, Santa Monica, California, Dec. 2, 1961. Division of Secondary Education, Office of the Superintendent of the Los Angeles County Schools. December, 1961. (Mimeographed.)

1. To develop ideas of the nature of hypotheses and how they function in science.

2. To distinguish among hypothesis, assumption, and theory, and to develop ways in which each relates to the other in the context of scientific methodology.

3. To introduce the purpose and use of controls in scientific experimentation.

4. To introduce the nature of data and the relationship of data to hypotheses, assumptions, and theories.

These objectives developed as a consensus out of discussions which carried potential shifts of emphasis that became important and recurrent concerns of the participants. The relative emphasis to be given theory was discussed. The limited laboratory experiences and the lack of precision in general usage of the term, by both teachers and students, were factors which resulted in an agreement to limit the assessment of student understanding of theory until the students had had more experience with the nature of theory as it is used more precisely in the sciences. The nature and function of hypotheses were to be given primary emphasis in the test since the laboratory exercises and other experiences of the students during this period of instruction emphasized this aspect of science. It was thought that the relationships between hypotheses and assumptions in experimental design were given sufficient attention in discussions, the laboratory, and the textbook to warrant inclusion in a test. Assessment of the nature of assumption was to be accomplished by means of a written description of an experimental situation rather than a more abstract definition.

In the judgment of the participants the students were provided with enough experience with controls and controlled experimentation to include assessment of aspects of the nature of controls in a test instrument. The discussion of this aspect of the nature of science included the idea of the variable in an experiment. Since the term "variable" was introduced only in laboratory work and was not a part of the text material, the participants felt that the ideas of the variable, but not the term itself (at this point), was important. The terms "empirical," "quantitative," and "qualitative" were discussed; but the varied emphases given the ideas associated with these terms, and the lack of agreement as to their importance at this time, resulted in the elimination of the use of such terms in questions, or, as questions.

The students were introduced to graphing data which required extensive instructional time, thus a question requiring graph reading was suggested for inclusion in a test instrument.

The problem of scientific terminology, whether used in context in a question or as the point of assessment, became a major concern in planning this test and the other tests which were used during the year. For example, questions were raised by participants as to whether it was necessary for a student to distinguish between "assumption" and "hypothesis"; the matter of how extensive students (with their limited experience at this point in the year) might be able to understand these terms was fully discussed. It was agreed that Test 41 might include the terms "assumption," "hypothesis," "control," and "data" and in that way provide for bench marks at the beginning of the year which could be compared with growth achieved at the different points during the year.

The Test

When completed, the test contained four areas of emphasis: the nature and function of hypotheses, the idea of controls in experiments, interpretation of graphed data, and the nature of data. The test was designed as a core test composed of ten questions to which teachers would add questions to assess aspects of study that they felt were important and not assessed by the core test. The test that resulted contained five questions, or 50 percent of the core test, on hypotheses; three questions, or 30 percent, on controls; one question, or 10 percent, requiring the interpretation of an experimental record of data. A grid of the test questions by their question number and content by the classification system developed in the *Taxonomy*[1] is shown in the table below.

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[1] Bloom, *loc. cit.*

TABLE 3.1

Test Analysis Grid for Test 41

(Using the Taxonomy on the horizontal axis)

CONTENT	1.00 Knowledge			2.00 Comprehension			4.00 Analysis		
	1.10	1.20	1.30	2.10	2.20	2.30	4.10	4.20	4.30
The Nature and Function of Hypothesis	1 6			3 5			9		
The Idea of Controls in Experiments	4	2					8		
Interpreting Graphed Data				7					
The Nature of Data							10		

Using the terminology developed in the Taxonomy, 40 percent of the questions are classified by the project director as assessing aspects of knowledge (1.00) and 60 percent as assessing understanding and skills (2.00 and above) at the levels of comprehension and analysis. A copy of the test as given to the students in the test group follows.

TEST TITLE: The Nature of Science Test Number: 41

DIRECTIONS: Write the test number and title, your name, period, teacher, and date on your answer sheet. Mark the best answer by filling in the bubble exactly as shown in the sample. Use only the special pencil in marking your answer sheet. Erase completely any marks you change. DO NOT MARK ON THIS PAPER.

1. Which of the following statements helps to show the ways in which a hypothesis assists the scientists?

   a. Helps him in determining why he should use certain materials.
   b. Helps him draw the conclusion which he had decided was correct.
   c. Helps him convince other scientists that he was correct.
   d. Helps him make a prediction.
   e. Helps him in developing testing procedures.

2. Which of the following means most nearly the same as the word "control" as used in describing a scientific experiment?

   a. preliminary trial experiment.
   b. experiment with the variable factor.
   c. repeat experiment.
   d. comparison experiment.
   e. none of the above.

3. As developed in our laboratory work, one of the major functions of hypotheses is

   a. to make each experiment have the same form as the others.
   b. to determine the only way in which the experiment is done.
   c. to determine the data to be collected.
   d. to give the correct solutions.
   e. to make the experiment come out according to what is known to be true.

4. A control in an experiment is

   a. a point at which the experimenter makes observations.
   b. a standard against which the experimenter can measure the outcome of his experiment.
   c. the careful measurement and record keeping of the experimenter.
   d. the part in which the experimenter introduces the variables.
   e. the part in which the experimenter does nothing.

5. Which of the following statements is most similar to a scientific hypothesis? In the 1960 presidential election:

   a. Mr. Kennedy secured his greatest majorities in cities.
   b. The defeat of Mr. Nixon may be related to shifts in the voting patterns of certain religious and political minorities.
   c. Mr. Nixon should have won.
   d. Both Mr. Kennedy and Mr. Nixon secured votes from areas where such numbers of votes had not been predicted.

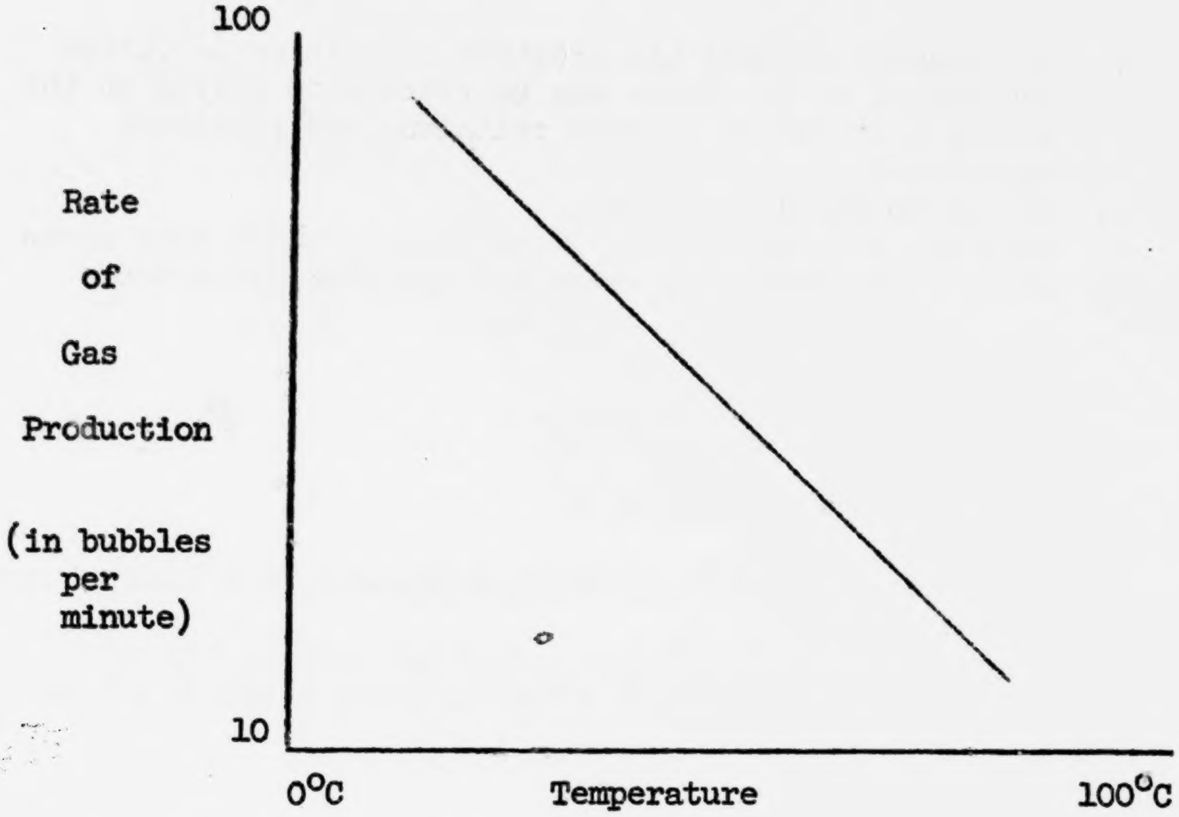
-2-*

6. An hypothesis is

   a. an explanation of a situation supported by a limited amount of evidence.
   b. a basic assumption that a scientist uses in his work.
   c. an explanation which is established as a result of research.

Retyping of the tests for inclusion in this report has necessitated some rearrangement of test questions. The page numbers (-2-, etc.) indicate the actual page breaks on the test as administered to the students. The asterisk (-- with the page number) in all subsequent tests will indicate the actual page breaks for these tests.

Interpretation of Graphs



7. From the graph above, one could conclude that

   a. the rate of gas production increases as the tempera increases.
   b. the rate of gas production decreases as the temperature increases.
   c. the rate of gas production decreases as the temperature decreases.
   d. the rate of gas production is independent of temperature.
   e. the rate of gas production decreases and then increases as the temperature increases.

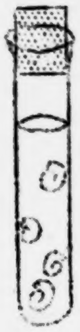
Bromthymol blue is an acid-base (alkali) indicator:

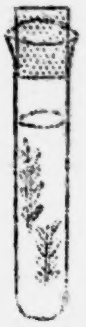
yellow in the presence of an acid,
blue-green in a neutral solution,
blue in the presence of a base.

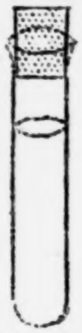
Carbon dioxide is a gas produced by living things after the breakdown of certain substances in their bodies. When dissolved in water carbon dioxide produces an acid reaction in the presence of acid-base indicators.

In order to find out if both green plants and animals produce carbon dioxide three test tubes with similar amounts of blue-green colored bromthymol blue and water were placed in a test tube rack.

Tube C was sealed. Several water snails were placed in tube A, several pieces of a water plant were placed in tube B, and each tube was sealed. All three tubes were placed in a lighted room. Three hours later the bromthymol in tube A was yellow, in tube B was blue, and in tube C was blue-green.


Tube A


Tube B


Tube C

On the basis of the discussion above, answer questions 8 to 10.

8. The "control" tube (or tubes) in this experiment

   a. is tube A.
   b. is tube B.
   c. is tube C.
   d. are tubes A and B.
   e. is missing.

9. Of the statements below, the best statement of the hypothesis being tested is

   a. Do green water plants and water snails both produce carbon dioxide gas when placed in similar situations?
   b. Does bromthymol blue change color in the presence of carbon dioxide gas?
   c. Does the presence or absence of light effect the production of carbon dioxide gas in living things?
   d. Does sealing of test tubes effect the production of carbon dioxide gas in living things?
   e. Does the addition of bromthymol blue to water effect the production of carbon dioxide gas in living things?

10. The data collected as a result of the experiment were

    a. bromthymol blue is yellow in the presence of an acid and blue in the presence of a base.
    b. tubes with snails change bromthymol blue to a yellow color and tubes with green plants to a blue color.
    c. water snails produce carbon dioxide under conditions in which green water plants do not produce carbon dioxide.
    d. green water plants produce carbon dioxide under conditions in which water snails do not produce carbon dioxide.
    e. carbon dioxide gas produces color changes in bromthymol blue.

Analysis of Test Results

The mean achievement of all students on Test 41 was 5.9 raw score points, or 59 percent, and the standard deviation was 2.1 raw score points. Table 3.2 shows the frequency of total correct responses by the students taking the test.

TABLE 3.2

Distribution of Correct Scores for Test 41

NUMBER OF CORRECT CHOICES*	BOYS		GIRLS		TOTAL	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
10	8	2.4	6	1.8	14	2.1
9	30	9.2	25	7.5	55	8.3
8	39	11.9	53	15.9	92	14.0
7	50	15.4	56	16.8	106	16.1
6	76	23.4	63	18.9	139	21.1
5	48	14.7	43	12.9	91	13.8
4	28	8.6	30	9.0	58	8.8
3	27	8.3	36	10.8	63	9.5
2	15	4.6	18	5.4	33	5.0
1	5	1.5	3	0.9	8	1.2
TOTALS	326	100.0	333	99.9	659	99.9

*10 is the maximum number possible.

A more detailed analysis of the response pattern on the test is provided in the item responses shown in Table 3.3 below.

TABLE 3.3

Item Responses to the Questions on Test 41: Test Group*

Question Number	a	b	c	d	e	Omit
1	6%	24%	1%	57%	11%	. .
2	3%	24%	3%	49%	20%	. .
3	5%	5%	49%	13%	27%	. .
4	3%	69%	7%	13%	8%	. .
5	11%	61%	3%	25%	. .	. .
6	48%	33%	19%	. .	. .	. .
7	22%	68%	6%	2%	2%	. .
8	1%	2%	89%	5%	3%	. .
9	68%	14%	3%	5%	9%	1%
10	8%	33%	39%	3%	15%	1%

*Expressed as a percentage of N. N = 659.

—— Correct response.

Questions 1, 3, 5, 6, and 9 were designed to assess selected aspects of the students' understandings of hypothesis. The average number of students responding correctly to this set of questions was 57 percent. In the schemata below the composition of the questions dealing with hypothesis and the percentage of correct responses to these questions are shown.

Test Composition

			% Correct (N = 659)
50% Hypothesis	20% Function	10% as used by scientists Q.1	. . . 57%
		10% as developed in laboratory Q.3	. . . 49%
	30% Identification	10% select a statement which is an hypothesis Q.5	. . . 61%
		10% select an appropriate statement of hypothesis Q.6	. . . 48%
		10% select statement of hypothesis from an experiment Q.9	. . . 68%
		Mean achievement for questions on hypothesis	. . . 57%

The success of students in selecting the best answers to the questions on hypothesis may be further clarified by examining the patterns of distractor selection. The schemata below indicates that in the judgment of the writer the students selected distractors which associated hypotheses with a priori correct statements in preference to prediction and experimental control in questions 1 and 3 respectively. Distractor selection in questions 5, 6, and 9, in the writer's judgment, indicated confusion of the term "hypothesis" with "data," "theory," and "variable."

Incorrect Response Patterns

			% Incorrect (N = 659)
Hypothesis as proof of a predetermined correct idea	Q.1b Q.1c	hypothesis is a predetermined correct finding	. . . 25%
	Q.3d Q.3e	hypothesis is a correct finding	. . . 40%
	Q.5a Q.5d	hypothesis is data	. . . 36%
Hypothesis confused with assumption, theory, data, and incorrect variables	Q.6b	hypothesis is assumption	. . . 33%
	Q.6c	hypothesis is theory	. . . 19%
	Q.9b	hypothesis is assumption	. . . 14%
	Q.9c Q.9d Q.9e	hypothesis is variable	. . . 17%

Thirty percent of the test assessed aspects of the students' understanding of control as shown in the schemata below.

Test Composition

		% Correct (N = 659)
30% Nature of Control	10% meaning of control Q.2	. . . 49%
	10% use of control by experimenter Q.4	. . . 69%
	10% select control in an experiment Q.8	. . . 89%

Selection of the control from a written description of an experiment was successfully accomplished by 89 percent of the students; but as the relationships of control were less related to an experimental situation, success dropped.

The previous discussion of the success of students on the various items within the test raises the question of who was successful and who was not. The first approach to answering this question was the separation of groups of students into those who were successful on Test 41 and those who were not: the Cans and the Cannots.[1]

Can-Cannot Analysis for Test 41

The indication of positive or negative discrimination, that is, whether the question favored the Cans or Cannots, the biserial correlation co-efficient (PBIS), the difficulty of the test expressed as a decimal equivalent of the proportion of all students (the test group) answering the question correctly are shown in the table below.

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[1] *Supra*, p. 17.

TABLE 3.4

Can-Cannot Analysis of Test 41

N = 659 Cans and Cannots each = 27% of N, or = 178

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		p_{BIS}	Difficulty
		N	%	Direction	Ratio		
1 . . .	Can	139	78%	+	2.1:1	0.43	0.57
	Cannot	66	37%				
2 . . .	Can	141	79%	+	3.6:1	.56	.49
	Cannot	40	22%				
3 . . .	Can	129	72%	+	3.4:1	.51	.49
	Cannot	37	21%				
4 . . .	Can	167	94%	+	2.7:1	.66	.69
	Cannot	63	35%				
5 . . .	Can	157	85%	+	2.4:1	.52	.61
	Cannot	62	35%				
6 . . .	Can	140	79%	+	3.4:1	.56	.48
	Cannot	41	23%				
7 . . .	Can	169	95%	+	2.7:1	.68	.68
	Cannot	62	35%				
8 . . .	Can	178	100%	+	1.4:1	.62	.89
	Cannot	125	70%				
9 . . .	Can	169	95%	+	3.2:1	.70	.68
	Cannot	54	30%				
10 . . .	Can	106	60%	+	4.6:1	0.51	0.33
	Cannot	23	13%				
AVERAGES					3.0:1	0.57	0.59

Each of the questions on Test 41 was a positive discriminator even though the range of difficulty of items varied from 0.33 to 0.89. The discrimination between the Cans and Cannots ranged from a high of 4.6:1 on question 10 to a low of 1.4:1 on question 8.

For the questions assessing aspects of hypothesis (questions 1, 3, 5, 6, and 9), in each instance the test group and the Cans selected the correct answer at a higher rate than any single distractor; in each instance the Cannots selected one or more distractors at a higher rate than the correct answer. The mean achievement on the five questions for the test group was 57 percent; the Cans, 83 percent; and the Cannots, 29 percent. The Cannots equated "hypothesis" with "assumption" or a predetermined correct finding in preference to the best response. In responding to one of three questions assessing understandings of controls, the Cannots selected "an experiment with the variable factor" in preference to "comparison experiment." For the graphing problem 44 percent of the Cannots selected the inverse of the correct response. The complete item responses of the Cans and Cannots are shown in Tables 3.5 and 3.6.

TABLE 3.5

Item Responses to the Questions on Test 41: Cans*

Question Number	a	b	c	d	e	Omit
1	3%	11%	1%	78%	7%	. .
2	. .	7%	1%	79%	12%	1%
3	2%	2%	72%	7%	17%	. .
4	. .	94%	1%	2%	4%	. .
5	6%	85%	1%	8%	. .	. .
6	79%	13%	8%	. .	. .	. .
7	4%	95%	1%	. .	. .	. .
8	. .	. .	100%	. .	. .	. .
9	95%	2%	1%	. .	2%	. .
10	1%	60%	38%	1%	2%	. .

*Expressed as a percentage of N. N = 178.

___ Correct response.

TABLE 3.6

Item Responses to the Questions on Test 41: Cannots*

Question Number	a	b	c	d	e	Omit
1	7%	39%	2%	37%	15%	. .
2	4%	40%	6%	22%	28%	. .
3	10%	11%	21%	20%	38%	. .
4	7%	35%	17%	28%	12%	. .
5	15%	35%	4%	45%	1%	. .
6	23%	48%	28%	1%	1%	. .
7	44%	35%	10%	5%	6%	. .
8	4%	5%	70%	16%	5%	. .
9	30%	31%	8%	12%	19%	. .
10	19%	13%	31%	8%	28%	1%

*Expressed as a percentage of N. N = 178.

—— Correct response.

When interpreting the differential responses of Cans, Cannots, and the Test Group on Test 41, the reader will recall that the students tested were above average in DAT (VR + NA) test scores. Scores for the DAT (VR + NA) of the Test Group, Cans, and Cannots based upon the test publisher's percentile conversion tables are shown in Figure 3.1.

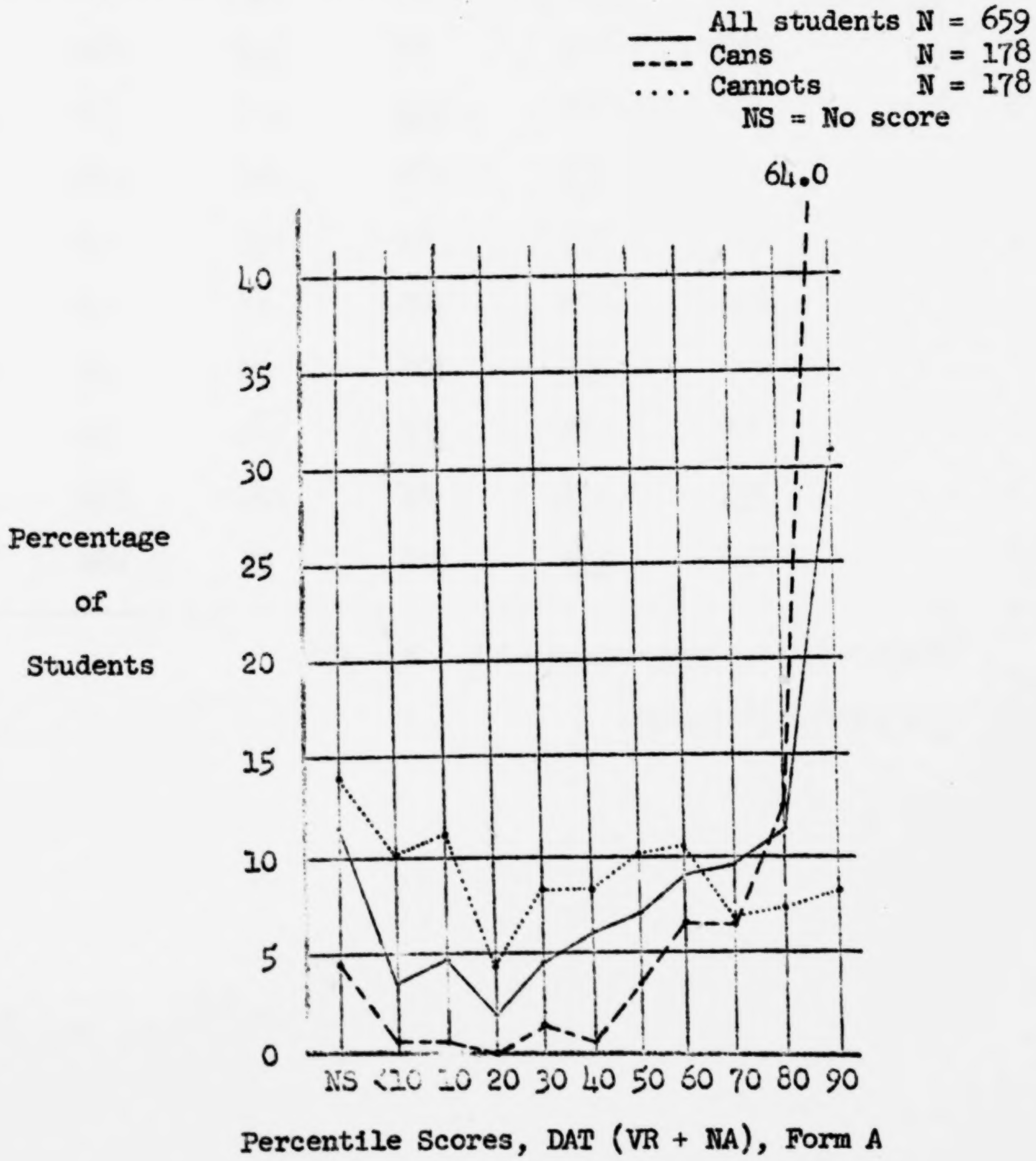

Fig. 3.1.--Frequency distributions for students taking Test 41 by publisher's percentile scores on the DAT (VR + NA).

The median score of the Cans falls above the 90th percentile, for the Test Group at about the 60th percentile, and for the Cannots at about the 40th percentile.

Test 42, Understanding Biological Classification

Development of the Test

Test 42 was developed from a fifteen question test which was given in 1961-62 to 716 students in five high schools in Los Angeles County. Each of the questions in this test had been evaluated and found to be a positive discriminator between the Can and Cannot groups.

The 1961-62 teacher participants had discussed the central ideas which they wished to develop in the introduction to biological classification which they hoped the students would begin to understand. The 1961-62 tests had been developed to assess four objectives:

1. To understand the historical background of the contemporary system of biological classification.
2. To understand the hierarchy of taxonomic groups and the relations among these groups.
3. To understand the nature and bases of the contemporary system of biological classification.
4. To understand the biological concept of species.

As a result of the discussion of the test questions which had been previously administered, the participating teachers in 1962-63 agreed to eliminate the two questions which dealt with the history of the system of classification. In addition it was agreed to eliminate objective one on historical understanding from the 1962-63 test but to retain the remaining 1961-62 objectives.

The Test

When completed, the test contained three areas of emphasis: relations of taxonomic groups, including the scientific name; the basis of biological classification; and the concept of species. The test was designed as a core test composed of twelve questions to which teachers would add additional questions to assess aspects of the study which they felt were important and not assessed by the core test.

The test that resulted contained six questions, or 50 percent of the core test, on relationships of taxonomic groups, including two questions that dealt specifically with scientific name; four questions, or 33 percent, on the basis of biological classification; and two questions, or 17 percent, on the concept of species. A grid of the test questions by their number and their content by the classification system developed in the Taxonomy is shown in the table below.

TABLE 3.7

Test Analysis Grid for Test 42

(Using Bloom's Taxonomy on the horizontal axis)

CONTENT	1.00 Knowledge		2.00 Comprehension	3.00 Application
	1.20	1.30	2.20	3.00
Relationships of Taxonomic Groups	1 5 6 8			
Scientific Name	3 4			
Basis of Biological Classification	2 11	9	10	
The Concept of Species	12			7

Using the terminology developed in the Taxonomy, 88 percent of the test questions are classified by the project director as assessing aspects of knowledge (1.00) and 12 percent as assessing understanding and skills (2.00 and above) at the levels of comprehension and application. A copy of the test as given to the students in the test group follows.

TEST TITLE: Classification **Test Number:** 42

DIRECTIONS: Write the test number and title, your name, period, teacher, and date on your answer sheet. Mark the best answer by filling in the bubble exactly as shown in the sample. Use only the special pencil in marking your answer sheet. Erase completely any marks you change. DO NOT MARK ON THIS PAPER.

1. Ordinarily more resemblance exists among members of a class than among the members of

   a. a phylum.
   b. a family.
   c. a genus.
   d. a species.
   e. an order.

2. Biological classification of living organisms is based primarily upon

   a. structures having similar origins (developing from the same parts in the young).
   b. structures having similar functions (jobs to do).
   c. geographical distribution on the earth.
   d. foods they eat.
   e. use or harm to man.

For items 3-6 use the following key

a. Genus
b. Order
c. Phylum
d. Species
e. Class

3. The scientific name of the lion is Felis leo. In which of the five categories would Felis fall?

4. The scientific name of man is Homo sapiens. In which of the five key categories would sapiens fall?

5. In which of the five key categories are the greatest number of organisms included?

6. Which of the five key categories has the smallest number of groups?

7. The offspring of a male donkey and a female horse (mare) is a sterile animal (not able to have young) called a mule. This data would indicate that donkeys and horses are

   a. different species within the same genus.
   b. different varieties within the same species.
   c. the same species within the same genus.
   d. the same species within different genera.
   e. the same variety within the same species.

-2-*

8. In which of the following lists of the categories used in classification are the categories in their proper position?

   a. Phylum, class, family, order, genus.
   b. Phylum, class, order, family, genus.
   c. Phylum, family, order, class, genus.
   d. Phylum, order, class, family, genus.
   e. Order, phylum, family, class, genus.

9. A scientist grouped his collection of butterflies on the basis of color and size: all blue butterflies with a wingspread of 1/2 inch or less being placed in one group, etc. This kind of classification is based upon

   a. direct observation.
   b. a theory of butterfly relationships.
   c. a hypothesis about butterflies.
   d. none of these.

10. In Everyday Biology, a high school biology text, the following statement appears: "The various groups in this (biological) scheme of classification have been built up through a study of differences and likenesses in the structures of plants and animals. Therefore the scheme shows the relationships of one group to another with respect to structure." This system developed out of

    a. observation.
    b. hypothesis.
    c. observation and hypothesis.

11. Many people think that whales are fish. Biologists group them with mammals such as dogs and cats. The best explanation for this difference in grouping is that biologists use the system of classification developed by Linneaus in which living things are grouped by:

    a. their geographical distribution over the earth.
    b. structures which perform similar functions (do the same job).
    c. the foods they eat.
    d. their usefulness or the harm they do to man.
    e. structures which have the same origin in the young.

12. The dog, the jackal, and the coyote all belong to the genus Canis. Biologists group them into different species, however, because

    a. while they look alike in many ways, they compete for food in the same places.
    b. while they look alike in many ways, they are natives of different parts of the world.
    c. they were discovered by man over wide intervals of time.
    d. they cannot interbreed and produce fertile offspring.

Comments on Questions by Teacher Participants

After using the test and discussing the results of the test with students, teachers reported that there were wording problems on question 6. On this question students misinterpreted the meaning of "smallest number of groups." With this wording they could have responded with answer "d," "species," which was regarded as the correct answer; or answer "c," "phylum," which was the opposite of the correct answer. The teacher group felt that a rewording such as "in which of the five key categories would you find the smallest varieties of animals?" might be better. The item analysis indicates that response "c" was selected by 15 percent of the test group, which was only 2 percent more than the selection of answer "a," which was only 2 percent more than the selection of answer "b." It would not appear that this wording contributed markedly to errors of students on this particular question.

Analysis of Test Results

The mean achievement of all students on Test 42 was 7.7 raw score points, or 59 percent; and the standard deviation was 2.6 raw score points. Table 3.8 shows the frequency of correct responses by the students taking the test.

TABLE 3.8

Distribution of Correct Scores for Test 42

NUMBER OF CORRECT CHOICES*	BOYS		GIRLS		TOTAL	
	Frequency	Per-centage	Frequency	Per-centage	Frequency	Per-centage
12	9	2.9	24	7.3	33	5.0
11	36	11.0	36	10.8	72	10.9
10	40	12.2	51	15.4	91	13.8
9	35	10.6	44	13.3	79	12.0
8	48	14.6	33	10.0	81	12.3
7	42	12.8	37	11.2	79	12.0
6	36	11.0	35	10.6	71	10.8
5	35	10.6	33	10.0	68	10.3
4	26	7.9	20	6.0	46	7.0
3	15	4.6	12	3.6	27	4.1
2	3	0.9	5	1.5	8	1.2
1	3	0.9	1	0.3	4	0.6
TOTALS	328	100.0	331	100.0	659	100.0

*12 is the maximum number possible.

A more detailed analysis of the response pattern of the test is provided in the item responses shown below in Table 3.9.

TABLE 3.9

Item Responses to the Questions on Test 42: Test Group*

Question Number	a	b	c	d	e	Omit
1	59%	8%	6%	16%	11%	. .
2	74%	23%	2%	. .	. .	. .
3	55%	5%	10%	19%	10%	1%
4	14%	4%	5%	62%	13%	2%
5	9%	6%	65%	15%	5%	. .
6	13%	11%	15%	53%	7%	1%
7	61%	17%	6%	14%	1%	. .
8	6%	57%	10%	20%	7%	1%
9	86%	3%	3%	7%	. .	. .
10	34%	3%	61%	1%	1%	. .
11	3%	41%	1%	2%	52%	1%
12	1%	11%	3%	82%	1%	2%

*Expressed as a percentage of N. N = 659.

—— Correct response.

When the test was structured, questions 1, 3, 4, 5, 6, and 8 were developed to test aspects of the students' understandings of the relationships of taxonomic groups as indicated in the following analyysis.

Test Composition

			% Correct (N = 659)
Relationships among taxonomic groups 50%	33% Hierarchial groups	Q.1	59%
		Q.5	65%
		Q.6	53%
		Q.8	57%
	17% Scientific name	Q.3	55%
		Q.4	62%
	Mean achievement		58%

The distractor selection for the six questions designed to assess selected aspects of the relationships among taxa was fairly well distributed among the incorrect groups. For the two questions dealing with scientific name the selection for "genus" when "species" was correct and vice versa was more common than alternative selections. Of the 659 students 42 percent were unable to deal with the relations of taxonomic groups at this time in the course.

Four questions assessed selected aspects of the basis of biological classification as shown in the following schemata.

Test Composition

			% Correct (N = 659)
Basis of biological classification 34%	17% Basis of classification	Q. 2	74%
		Q.11	52%
	17% Kind of classification system	Q. 9	86%
		Q.10	61%
	Mean achievement		69%

In questions 9 and 10 the students were presented with two different descriptions of classification schemes. These questions have relation to the nature of science in that students were asked to select from among statements including the terms "observation," "theory," and "hypothesis." To question 9, 86 percent of the students responded correctly with "none of these" serving as the major distractor. With reference to question 10, 34 percent of the students regarded the statement as being based on observation alone. These students were unable to select the best answer from among only three choices. The choice of the correct answer required them to interpret from a word statement a deduced relationship which went beyond the observed data. Although both questions 2 and 11 were answered correctly by more than half of the test group, the major distractor was the same for each question. The basis of biological classification was associated with the structure-function relationship rather than with the common embryological origin of structures.

Incorrect Response Patterns

		% Incorrect (N = 659)
Biological classification is based on structures having the same function	Q. 2b	. . . 23%
	Q.11b	. . . 41%

Two questions were concerned with one aspect of the concept of species as shown in the following schemata.

Test Composition

			% Correct (N = 659)
Concept of species 17%	Species interbreed and produce fertile offspring	Q. 7	. . . 61%
		Q.12	. . . 82%
	Mean achievement		. . . 72%

Although student performance was relatively better on this section of the test which was concerned with the concept of biological species than with the two preceding sections, the errors made by the students on these two questions causes the investigator to question whether one would expect these students at this point (approximately 5 weeks of study) in a biology course to have had sufficient experience to deal with the relations among species, genera, and varieties in order to handle the distinctions required in question 7.

Can-Cannot Analysis for Test 42

Table 3.10 presents the relative achievement of the Can and Cannot groups on each question of Test 42. Tables 3.11 and 3.12 present the complete item responses of the Can and Cannot groups.

Each of the questions on Test 42 was a positive discriminator. The difficulty of test items ranged from 0.52 to 0.86, and the range of discrimination between the Cans and Cannots varied from a high of 8.0:1 on question 6 to lows of 1.4:1 on questions 9 and 10. On eight of the twelve questions 90 percent of the Can group selected the best answer. The most difficult questions, questions 10 and 11, were answered correctly by 71 percent and 72 percent respectively of these students.

Questions 2 and 11 required the students to discriminate between structures performing the same function and structures with the same embryological origin as a basis for classification. More Cannots selected distractor "b" on question 11 than the correct answer. Question 2 deals with this problem on the basis of biological classification at the level of generalization, whereas question 11 requires the students to interpret the statement regarding the classification of particular organisms. Although the Cannots did relatively well on both of these questions, they selected the major distractor "structures having the same function" at twice the frequency of the Cans.

In the writer's opinion the minimum requirement for success on Test 42 was that the students memorize the hierarchial relationships of the various taxa in the biological system of classification. The questions might be raised at this point, first, as to whether the Cannot group had failed to memorize the taxa and their relationships; and, secondly, whether the difference in ability to handle question 2 compared with question 11 may not indicate some assessment of analytical ability, for question 11 required the students to apply what could have been acquired by rote learning to a new set of data.

On the six questions dealing with the relations of taxonomic groups (questions 1, 3, 4, 5, 6, and 8) the average achievement of the Can group was 93 percent, and of the Cannot group 20 percent. These data may further support the writer's interpretation that the Cannot group failed to memorize (at the minimum level of "knowledge") the hierarchial arrangement of the taxa.

Questions 2, 9, 10, and 11, which dealt with the basis of biological classification, were answered successfully by 83 percent of the Can group and 57 percent of the Cannot group. Questions 7 and 12, which assessed aspects of the concept of species, were answered successfully by 94 percent of the Can group and 44 percent of the Cannot group.

On the total test, the mean achievement of the Can group was 90 percent and of the Cannot group was 36 percent. This lack of success on the part of the lowest achieving 27 percent of the students enrolled in the classes in this experimental study raises further instructional questions for general education in the biological sciences in the secondary school, questions which will be clarified in the conclusion of this report.

TABLE 3.10

Can-Cannot Analysis of Test 42
N = 659 Cans and Cannots each = 27% of N, or = 178

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		PBIS	Difficulty
		N	%	Direction	Ratio		
1 . . .	Can	173	97%	+	4.2:1	0.78	0.59
	Cannot	41	23%				
2 . . .	Can	157	88%	+	1.5:1	.30	.74
	Cannot	117	66%				
3 . . .	Can	162	91%	+	5.2:1	.72	.55
	Cannot	31	17%				
4 . . .	Can	169	95%	+	4.2:1	.74	.62
	Cannot	40	22%				
5 . . .	Can	174	98%	+	4.1:1	.80	.65
	Cannot	42	24%				
6 . . .	Can	160	90%	+	8.0:1	.76	.53
	Cannot	20	11%				
7 . . .	Can	160	90%	+	3.0:1	.63	.61
	Cannot	53	30%				
8 . . .	Can	159	89%	+	4.4:1	.68	.57
	Cannot	36	20%				
9 . . .	Can	176	99%	+	1.4:1	.62	.86
	Cannot	124	70%				
10 . . .	Can	127	71%	+	1.4:1	.19	.61
	Cannot	94	53%				
11 . . .	Can	128	72%	+	1.8:1	.32	.52
	Cannot	73	41%				
12 . . .	Can	173	97%	+	1.7:1	0.60	0.82
	Cannot	103	58%				
AVERAGES					3.4:1	0.59	0.65

TABLE 3.11

Item Responses to the Questions on Test 42: Cans*

Question Number	a	b	c	d	e	Omit
1	97%	1%	. .	. .	2%	. .
2	88%	12%	. .	. .	. .	. .
3	91%	2%	2%	4%	1%	. .
4	3%	1%	1%	95%	. .	. .
5	. .	1%	98%	2%	. .	. .
6	2%	1%	6%	90%	1%	1%
7	90%	5%	2%	2%	1%	1%
8	2%	89%	1%	8%	1%	. .
9	99%	1%	. .	. .	1%	. .
10	25%	3%	71%	1%	. .	. .
11	1%	26%	. .	1%	72%	. .
12	. .	3%	. .	97%	. .	. .

*Expressed as a percentage of N. N = 178.

—— Correct response.

TABLE 3.12

Item Responses to the Questions on Test 42: Cannots*

Question Number	a	b	c	d	e	Omit
1	23%	16%	13%	29%	19%	. .
2	66%	25%	6%	1%	2%	1%
3	17%	8%	19%	38%	15%	2%
4	27%	8%	13%	22%	25%	4%
5	20%	13%	24%	29%	13%	1%
6	28%	20%	26%	11%	14%	2%
7	30%	31%	10%	28%	1%	1%
8	11%	20%	25%	31%	11%	2%
9	70%	7%	10%	12%	1%	1%
10	34%	7%	53%	2%	2%	2%
11	6%	46%	2%	3%	41%	2%
12	4%	27%	6%	58%	2%	3%

*Expressed as a percentage of N. N = 178.

___ Correct response.

The differential responses of the Cans, Cannots, and Test Group for Test 42 need to be considered with the scores of each group on the DAT (VR + NA). These scores based upon the test publisher's percentile conversion tables are shown in Figure 3.2.

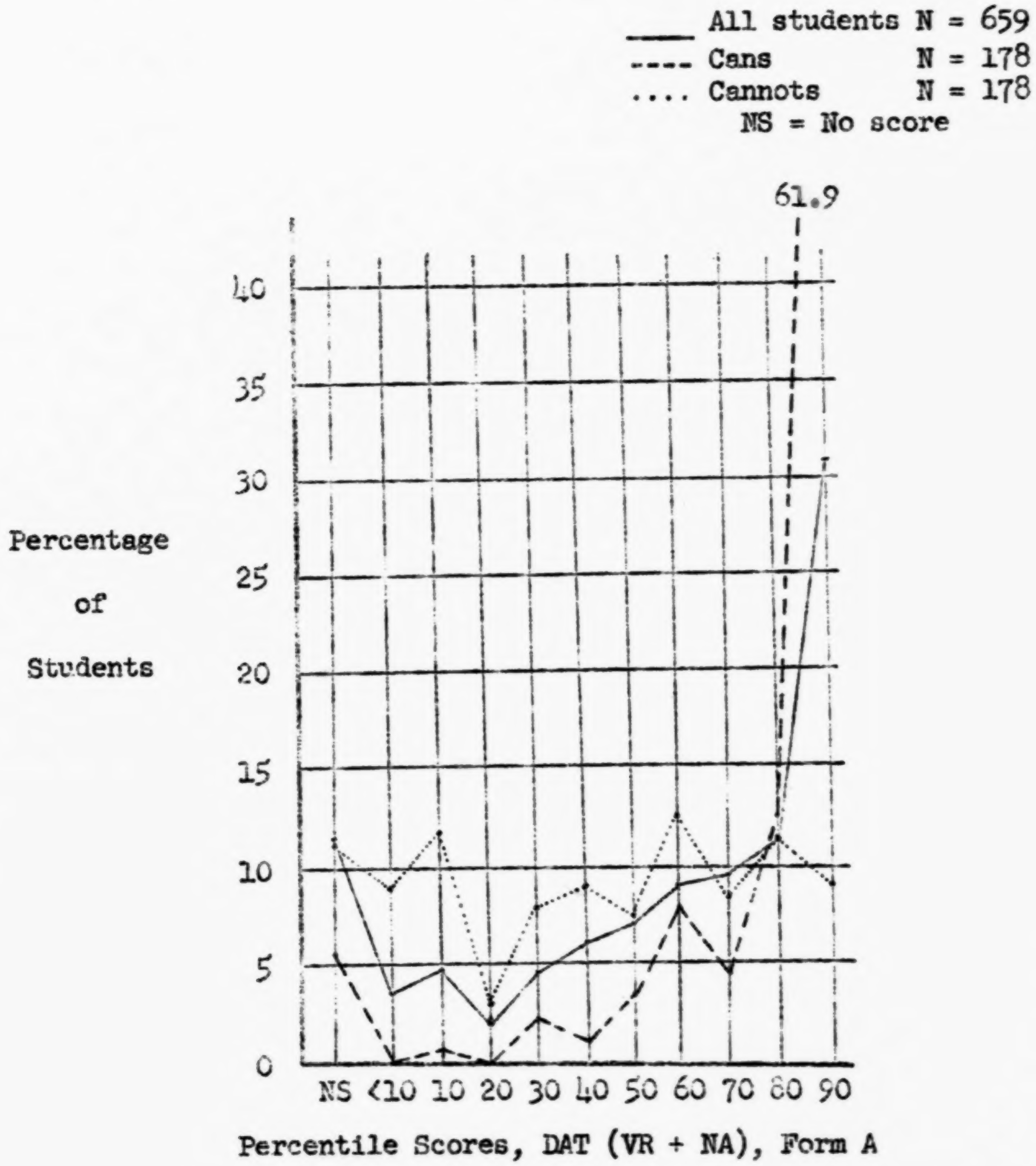

Fig. 3.2.--Frequency distributions for students taking Test 42 by publisher's percentile scores on the DAT (VR + NA).

The median score of the Cans falls above the 90th percentile, for the Test Group at about the 60th percentile, and for the Cannots at about the 50th percentile.

Test 43, Changes in Living Things

Development of the Test

Test 43 was developed from a forty-four question test which was given in 1961-62 to 723 students in five high schools in Los Angeles County. The statistical analysis of the questions on the earlier test had not been completed at the time Test 43 was developed, and the judgment of those teachers in the 1962-63 test development group, five of whom had participated in the 1961-62 testing, was used as a basis for modifying and accepting or rejecting particular questions from the 1961-62 test. The teacher participants proposed that Test 43 would deal with evolution and natural selection and with spontaneous generation and biogenesis. The major objectives of this area of study were:

1. To introduce the idea of evolution as understood by biologists, including variation, adaptation, natural selection, and the historical development of the contemporary evolution theory.

2. To contrast the points of view which Lamarck and Darwin proposed with regard to biological evolution and to discuss the experimental evidence which has been gathered in regard to these two approaches to explain the evolution of living forms.

3. To use the idea of spontaneous generation as a carrier for discussing the ways in which scientific hypotheses are developed, tested, and modified or rejected.

In discussing development of an instructional test to evaluate the objectives above, agreement was reached that the theory of evolution should receive the most prominent attention; that adaptation and variation should also be considered, but that comparative anatomy and the evidence for evolution should receive little attention; that the names of men in the history of evolution or spontaneous generation should not be emphasized, but that the development of these ideas might receive some attention. Since earlier instructional tests had shown lack of understanding of the ideas of hypothesis, assumption, and theory, the development of the idea of spontaneous generation--through experimentation in the laboratory and the historical discussion in the text--would be used to test further for understanding of these ideas.

The Test

When completed, Test 43 contained five areas of emphasis: evolution, spontaneous generation, adaptation, variation, and the nature of science. The test was designed as a core test composed of twenty questions to which teachers would add additional questions of their own. The test that resulted contained fourteen questions, or 70 percent of the core test, on evolution: its meaning, history, Lamarck's theory, and a comparison of the ideas of Darwin with Lamarck. Three questions, or 15 percent of the test, were concerned with the nature of science; and one question each, or 5 percent in each case, on spontaneous generation, adaptation, and variation. A grid of the test questions by their question number and content by the classification system developed in the Taxonomy is shown in the Table below.

TABLE 3.13

Test Analysis Grid for Test 43

(Using the Taxonomy on the horizontal axis)

CONTENT	1.00 Knowledge			2.00 Comprehension		4.00 Analysis
	1.10	1.20	1.30	2.20	2.30	4.20
Evolution: Meaning	12		8 11	15		
History		5				20
Lamarckian	1		10			
Darwin vs. Lamarck				13	14	
Evidence			6 7 9			
Spontaneous Generation	2					
Adaptation			17			
Variation				16		
Nature of Science: Theories			3	4		
Assumptions						19
Controls						18

Using the terminology developed in the Taxonomy, 55 percent of the test questions are classified by the project director as assessing aspects of knowledge (1.00) and 45 percent as assessing understanding and skills at the levels of comprehension and analysis (2.00 and above). A copy of the test as given to the students in the test group follows.

TEST TITLE: Changes in Living Things Test Number: 43

DIRECTIONS: Write the test number and title, your name, period, teacher, and date on your answer sheet. Mark the best answer by filling in the bubble exactly as shown in the sample. Use only the special pencil in marking your answer sheet. Erase completely any marks you change. DO NOT MARK ON THIS PAPER.

1. Four of the statements below describe the Lamarckian theory correctly. One does not describe the Lamarckian theory correctly. Which one does not?

   a. It is simple and clear.
   b. It is probably wrong.
   c. It has been backed by evidence.
   d. It shows that inheritance can be effected by the environment.
   e. It states that acquired characteristics are inherited.

2. The meaning of spontaneous generation to the biologist is

   a. the appearance of life from non-life.
   b. the idea that material can cause itself to catch fire.
   c. that maggots can be produced spontaneously from garbage.
   d. that mice will develop from dirty rags.
   e. that living things can come only from other living things.

3. Four of the following statements are accurate statements about theory. Which one is not an accurate statement about theory?

   a. Theories must be tested against accumulated knowledge.
   b. Theories are frequently revised as new knowledge becomes available.
   c. Theories are of greater interest to science as they are able to explain more and more.
   d. A theory shows what are the purposes, meanings, and values of life.
   e. A theory is developed to account for a body of knowledge.

4. One of the following statements best explains why biologists today support the theory of evolution:

   a. Charles Darwin developed the theory.
   b. Over a long period of time the theory has developed in such a way that it enables scientists to explain more and more.
   c. Over a long period of time the theory has remained as it was first developed which shows its truth.
   d. The theory has not had to be tested to find out if it was true.
   e. The theory explains how animals and plants in the past are related to those now living.

5. One of the following statements had been well developed and was known to Darwin at the time of his work:

   a. the science of comparative embryology.
   b. the findings of Mendel on inheritance.
   c. the classification system of Linnaeus.
   d. the science of paleontology which had revealed many fossils that could be arranged in a series.

For the next six questions select from the following key the statement which best applies, then mark the answer space corresponding to its letter. Questions 6 to 11.

   a. Theory of organic evolution accepted by most biologists.
   b. Basic assumptions upon which most of the evidence of organic evolution is founded.
   c. Evidence that the evolution of living things has taken place.
   d. Incorrect understanding about the theory of organic evolution.

6. Fossil record of the horse.

7. If two living things have similar structures they are closely related.

8. Gradual change in living things occurs as a result of the interaction of variations within a species. The total environment thus determines which members of the species will survive.

9. The skeletons of the horse, man, frog, and ape have corresponding parts--they have homologous skeletal parts.

10. Gradual changes of food habits in man have caused the shortening of the jaw and occasional absence of wisdom teeth.

11. All living things possess inheritable variations.

12. Which of the following is the best statement of what evolution means to the biologist?

   a. Everyone should be concerned about change.
   b. Plant species which lived in the past could not live again.
   c. Change occurs at the same speed and in the same way at all times.
   d. Because change cannot really be understood, it is best to develop a classification system by which differences can be understood.
   e. Living things change.

13. Darwin's theory differs from Lamarck's in that in Darwin's theory

    a. species are assumed to be changing.
    b. variation within a species is basic to the theory.
    c. use and disuse is a basic cause within the theory.
    d. selection of the organisms best adapted to the environment is basic to the theory.
    e. natural selection of inherited traits that occur by chance is basic to the theory.

-3-*

Items 14 and 15 are based upon the following situation:

> The great auk, which became extinct in 1844, was the only bird in the northern hemisphere which could not fly. It lost the power of flight through disuse of its wings.

14. "It lost the power of flight through disuse of its wings," would be an explanation made by:

    a. Darwin.
    b. DeVries.
    c. Malthus.
    d. Mendel.
    e. Lamarck.

15. Which one of the following statements best explains the present scientific standing of the explanation given above?

    a. It has stood the test of time and has been tested successfully many times by both scientists and non-scientists.
    b. It is very important to an understanding of how evolution probably takes place.
    c. It helps explain how mutations occur.
    d. It is not considered to be correct by most scientists.
    e. It is controversial among present-day scientists since there is no agreement as to whether it is correct or not.

16. Streptomycin (an antibiotic like penicillin) has been found to destroy the germ causing tuberculosis. After a year of treatment a student was told that he was infected with a variety of tuberculosis germ which was not effected by streptomycin (the germ was now streptomycin-resistant). The best explanation of this event would be that:

    a. streptomycin-resistance in the germs developed because of the treatment.
    b. streptomycin-resistance may be a rare but normal variation in the germ.
    c. streptomycin effected the germs in such a way that they made chemicals which destroy it.
    d. streptomycin acts on germs in such a way that their inheritable characteristics changed.

17. Four of the statements below are correct meanings of the term adaptation. Which statement is not a correct meaning of the term adaptation as it is used in modern biology?

    a. It is an inherited characteristic which improves the chances of a living thing to survive.
    b. It is the result of natural selection.
    c. When a living thing is said to be adapted to its environment, we mean that the living thing changes during its lifetime to meet the necessary conditions for life in its environment.
    d. The ancestors of a living thing had characteristics which allowed them to live and reproduce more effectively than similar living things without these characteristics.
    e. As a result of natural selection, most members of a species come to have characteristics which best allow them to survive in a given environment.

-4-*

Redi, in trying to test the hypothesis of spontaneous generation, set-up the following experiment:

> "I put a snake, some fish, some eels of Arno, and a slice of milk-fed veal in four, large, wide-mouthed flasks; having well-closed and sealed them, I then filled the same amount of flasks in the same way, only leaving these flasks open."

18. The "control" in this experiment is that

    a. all the jars contained the same kind and amount of meat.
    b. four of the flasks were sealed and four remained open.
    c. the experiment was set up in each set of four flasks at the same time in July.
    d. he assumed that spontaneous generation was not true.
    e. he assumed that spontaneous generation was true.

19. The basic assumption which led Redi to design the above experiment was that

    a. worms are found on dead bodies.
    b. worms found on dead bodies and decayed plants are insect larvae.
    c. all forms of living plants and animals were created during the creation of the Earth and there have never been any kinds of plants and animals produced since.
    d. animals deposit their eggs on decaying plant and animal material.
    e. the eggs of animals find food on which to develop in decayed material.

20. A fact well known to most people in Redi's time which led him to design the above experiment was that

    a. the eggs of animals find food on which to develop in decayed material.
    b. all forms of living plants and animals were created during the creation of the Earth and there have never been any kinds of plants or animals produced since.
    c. worms found on dead bodies and decayed plants are insect larvae.
    d. worms are found on dead bodies.
    e. animals deposit their eggs on decaying plant and animal material.

Comments on Questions by Teacher Participants

Due to the meeting schedule for the work group, suggestions were made for future revisions of Test 43 prior to its administration. It was suggested that in question 1, answer "d," the word "affect" should replace "effect." Teachers from the 1961-62 testing program had felt that students had difficulty with the words "bacteria" and "streptomycin."

In question 16, the word "bacteria" was replaced with "germ" and the word "streptomycin" was defined in order to improve this question's readability. Further discussion of question 16 indicated that the use of the word "because" in answer "a" was inadequate and many different rephrasings were suggested. The statement with "because" seemed to show purpose and therefore seemed to be Lamarckian. It was also suggested that the distinction between answers "a" and "b" was too difficult for students to make. It was finally agreed that answer "a" might be better worded "streptomycin resistance in the germs developed to overcome the streptomycin."

In question 7 the words "similar in structures" was thought to be too difficult an idea for students in the latter part of the second month of the school year. The teachers agreed that their students would not know the terms "homologous" and "analogous" so these terms should be avoided. It was finally agreed that question 7 might better be written "When two living things have similar structures they are closely related" which would change the answer from "b" to "d." In the lead to questions 14 and 15 it was suggested that the word "situation" be eliminated and a colon be placed after the word "following."

Although not discussed during the meeting, in question 5 the word "statement" can be deleted from the lead so that it would read: "One of the following had been well developed and was known to Darwin at the time of his work."

These specific suggestions were not incorporated into Test 43 in some instances since the test had been mimeographed and the teachers preferred to use it as prepared.

The test from the 1961-62 program, from which several questions were selected for building Test 43, was reviewed once more by participating teachers. They recalled that many of the questions had scientific terms which they had not emphasized even though tese terms had been introduced in the text. During 1961-62 one of the teachers, who had participated that year in the test development program and who was a member of the 1962-63 group, had 106 students circle words they did not understand on the test. This list of words was used as a basis for controlling vocabulary loading for the development of Test 43.

Following the administration of the test, further comments were made suggesting the improvement of some of the phrasing in the questions. With regard to the stem of question 18 which reads "the control in this experiment is that," it was suggested that an improved phrasing might be "the part of the experiment above which contains the control."

Analysis of Test Results

Table 3.14 presents the frequency of correct responses by the students taking the test. The mean achievement of all students on Test 43 was 10.2 raw score points, or 51 percent, with a standard deviation of 3.5 raw score points. The mean biserial correlation for the twenty questions was 0.46. Two questions were outside of the desired range of

TABLE 3.14

Distribution of Correct Scores for Test 43

NUMBER OF CORRECT CHOICES*	BOYS		GIRLS		TOTAL	
	Frequency	Per-centage	Frequency	Per-centage	Frequency	Per-centage
20	. .	. .	1	0.3	1	0.2
19	. .	. .	1	0.3	1	0.2
18	4	1.2	1	0.3	5	0.7
17	5	1.4	6	1.8	11	1.6
16	16	4.6	10	3.0	26	3.8
15	15	4.3	19	5.6	34	5.0
14	23	6.6	20	5.9	43	6.3
13	37	10.7	30	8.9	67	9.8
12	31	9.0	37	11.0	68	10.0
11	34	9.8	29	8.6	63	9.2
10	37	10.7	39	11.6	76	11.1
9	30	8.7	33	9.5	63	9.2
8	31	9.0	29	8.6	60	8.8
7	31	9.0	30	8.9	61	8.9
6	20	5.8	20	5.9	40	5.9
5	17	4.9	10	3.0	27	4.0
4	9	2.6	11	3.3	20	2.9
3	3	0.9	8	2.4	11	1.6
2	1	0.3	3	0.9	4	0.6
1	2	0.6	1	0.3	3	0.4
TOTALS	346	100.1	338	100.1	684	100.2

*20 is the maximum number possible.

biserial correlation: question 18 with a biserial correlation of 0.20 and question 19 with a biserial correlation of 0.16. Upon further analysis of question 19, it is the writer's own judgment that the best answer would be "d," but the key as developed, discussed, and used during the testing period indicated the best answer as "c." The frequency responses of all the students and of Can and Cannot students follow more closely the pattern of the correct answer as "d"; and "d" as the best answer would follow if the questions were read in a sequence of questions 18, 19, and 20, with the best answer being related as planned to Redi's hypotheses and assumptions rather than to the beliefs of the times which Redi himself believed to be fallacious. While calculation of the mean biserial correlation does not significantly change with a shift of question 19 from a biserial correlation of 0.16, if answer "c" is considered the best answer, to 0.12, if answer "d" is considered to be the best answer, the success on the question is shifted as shown in the item analysis.[1]

A detailed response pattern of the students on the test is shown by the item analysis presented in Table 3.15. The item responses for the Cans and Cannots are presented in Tables 3.16 and 3.17 respectively. Data for the discussion which follows were obtained from these three tables.

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[1] *Infra*, pp. 93-95.

TABLE 3.15

Item Responses to the Questions on Test 43: Test Group*

Question Number	a	b	c	d	e	Omit
1	5%	19%	51%	12%	13%	1%
2	68%	1%	3%	1%	26%	1%
3	5%	8%	10%	67%	9%	1%
4	1%	49%	14%	1%	34%	1%
5	8%	12%	64%	15%	. .	1%
6	6%	6%	84%	2%	. .	1%
7	18%	39%	8%	33%	. .	1%
8	49%	30%	8%	12%	. .	1%
9	12%	20%	44%	21%	. .	2%
10	8%	10%	44%	35%	. .	2%
11	43%	33%	8%	13%	1%	2%
12	. .	1%	1%	16%	81%	1%
13	8%	11%	6%	25%	50%	1%
14	17%	3%	7%	5%	68%	1%
15	9%	23%	10%	37%	19%	2%
16	37%	34%	8%	20%	. .	1%
17	12%	14%	47%	19%	6%	2%
18	15%	58%	13%	8%	4%	2%
19	11%	16%	10%	46%	15%	2%
20	11%	11%	15%	49%	13%	2%

*Expressed as a percentage of N. N = 684.

—— Correct response.

TABLE 3.16

Item Responses to the Questions on Test 43: Cans*

Question Number	a	b	c	d	e	Omit
1	1%	6%	79%	8%	7%	. .
2	91%	. .	1%	. .	9%	. .
3	3%	2%	4%	88%	3%	1%
4	. .	68%	13%	. .	18%	1%
5	3%	5%	85%	7%	. .	. .
6	2%	2%	95%	. .	. .	1%
7	9%	50%	6%	34%	1%	1%
8	76%	15%	2%	7%	. .	. .
9	5%	15%	66%	14%	. .	.
10	3%	2%	35%	59%	. .	1%
11	33%	55%	3%	7%	1%	2%
12	. .	. .	. .	7%	93%	. .
13	2%	5%	1%	17%	74%	1%
14	2%	1%	1%	1%	95%	. .
15	3%	8%	3%	80%	5%	1%
16	24%	61%	1%	14%	. .	1%
17	7%	5%	74%	8%	4%	1%
18	15%	67%	13%	4%	1%	1%
19	11%	15%	17%	49%	8%	1%
20	5%	9%	7%	72%	6%	1%

*Expressed as a percentage of N. N = 184.

___ Correct response.

TABLE 3.17

Item Responses to the Questions on Test 43: Cannots*

Question Number	a	b	c	d	e	Omit
1	11%	37%	24%	14%	13%	2%
2	38%	3%	6%	3%	49%	2%
3	9%	14%	20%	37%	19%	1%
4	3%	33%	18%	. .	45%	1%
5	17%	18%	37%	26%	. .	2%
6	15%	15%	61%	6%	1%	3%
7	27%	26%	16%	30%	. .	2%
8	25%	38%	20%	15%	. .	2%
9	18%	30%	23%	26%	1%	3%
10	11%	17%	48%	21%	1%	3%
11	43%	18%	17%	19%	1%	2%
12	1%	2%	3%	32%	60%	2%
13	16%	15%	12%	26%	29%	3%
14	33%	5%	13%	10%	38%	2%
15	16%	32%	14%	4%	31%	3%
16	40%	13%	20%	25%	1%	2%
17	16%	26%	21%	26%	8%	4%
18	17%	48%	12%	10%	10%	3%
19	10%	16%	7%	38%	24%	5%
20	20%	14%	24%	21%	17%	4%

*Expressed as a percentage of N. N = 184.

___ Correct response.

Test Composition and Analysis of Results

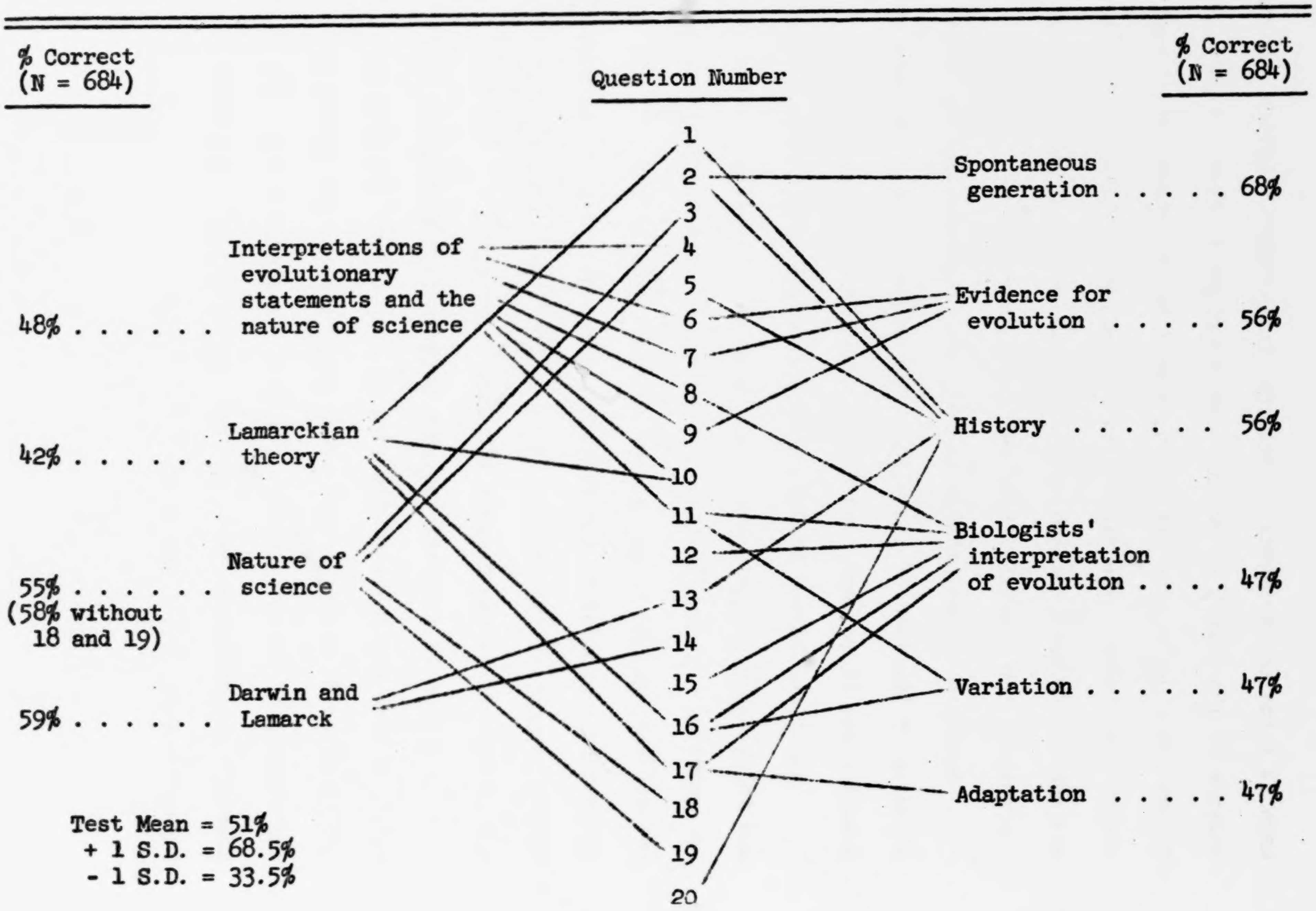
The composition of Test 43 may be considered in several ways. In general, with the exception of four questions, each of the remaining sixteen questions included knowledge or understandings and skills related to the development of theories of evolution, the current theory of evolution as developed in the text, and the relations of historical antecedents, such as spontaneous generation and Lamarck's theory, to current evolutionary theory. Many of the questions may be considered to include assessment of different aspects of evolutionary theory. Table 3.18 illustrates the writer's analysis of the relation of different objectives as discussed previously. This table includes also the percentages of the total students (N = 684) who answered each question correctly. Each of the subset of questions will be discussed separately.

The first set of questions to be discussed will be that which is classified under the rubric "Biologists' interpretation of evolution." These questions were judged by the writer to assess various dimensions of the biologists' interpretation of evolution even though they may be considered also to measure other aspects of changes in living things. The questions in this group are 8, 11, 12, 15, 16, and 17. Each of these questions presented some statement related to evolutionary theory. The mean success of all students on this series was 47 percent; 73 percent of the Cans and 24 percent of the Cannots answered the series of six questions correctly.

Questions 8 and 11 have the same four possible answers. In these two questions the major distractors were between "theory" and "assumption." Perhaps some of the difficulty with these two questions might be

TABLE 3.18

Composition of Test 43


% Correct (N = 684)
Question Number
% Correct (N = 684)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
48% . . . . . . Interpretations of evolutionary statements and the nature of science
42% . . . . . . Lamarckian theory
55% . . . . . . Nature of science
(58% without 18 and 19)
59% . . . . . . Darwin and Lamarck
Spontaneous generation 68%
Evidence for evolution 56%
History 56%
Biologists' interpretation of evolution 47%
Variation 47%
Adaptation 47%
Test Mean = 51%
+ 1 S.D. = 68.5%
- 1 S.D. = 33.5%

seen in terms of part-whole relations where number 8 states one simple version of the theory of organic evolution and 11 states a part of the theory which deals with variation, a part which becomes an assumption within the theory. The difficulties in distinguishing between theory and assumption were pointed out previously and remained with many students at the time this test was administered.[1]

Question 12 was planned to test the simplest level of understanding of the idea of evolution. The success of all students on this question was 81 percent, and of the Cannot group 60 percent.

Questions 15 and 16 deal with the relationships between acquired and inheritable characteristics in terms of biologists' interpretation of evolution. It was on these two questions that the distinctions between the Can and Cannot groups appeared most marked. Of the Cans 80 percent responded to the best choice for question 15, as compared with 4 percent of the Cannots; to question 16, 61 percent of the Cans and 13 percent of the Cannots responded correctly.

Question 17 attacked the same problem from a slightly different point of view and included the idea of adaptation. In this question the required distinction is between adaptation as the inherited characteristic and adaptation as a behavioral adjustment. The various meanings of adaptation in biological literature and in general usage made this a difficult question.

Understanding Lamarck's theory and Lamarckian thinking is necessary to understanding the history of the development of biological thought. The writer's experience in teaching high school students and the experience of the participating teachers indicated that commonsense language and thought as expressed by students at the high school level exhibit a great deal of Lamarckian thinking. Questions 1, 10, 16, and 17 form a set of questions which were designed to assess choices students would make when confronted with statements consistent with Lamarck's in a matrix of statements which were increasingly close to that of contemporary biologists. On this series of four questions, the total group of 684 students averaged 66 percent correct; of the Can group 68 percent responded correctly and of the Cannot group 20 percent were able to handle the questions correctly.

Question 1 was developed to test the lowest level of understanding within the series of four. In this case the question was asked directly with regard to selecting a response which did not describe Lamarck's theory, and the best answer was provided in a series of statements which correctly described Lamarck's theory with one exception. The Cannot group had difficulty with this question in that they selected the answer "It is probably wrong" rather than the negative answer which was desired, a negative answer being one that did not describe Lamarck's theory correctly. Selecting the incorrect in a series of correct responses seemed to provide a great deal more difficulty for students than series where there was one best answer in a series of incorrect or partially correct answers. We may regard the 37 percent of the Cannots who selected

"It is probably wrong" for Lamarck's theory as responding at a higher level of understanding than those students who selected as a correct response one of the three correct statements about Lamarck's theory. It we add this 37 percent to the 24 percent who marked the question correctly, the responses of the Cannot group are up markedly and indicate that, in the opinion of the writer, students had learned, at least for purpose of verbal recognition, that Lamarck's theory was not considered correct and/or was not backed by evidence.

Question 10 asked the students to relate cause and effect of a structural change with a statement regarding the theory of evolution. In this case 59 percent of the Cans and 21 percent of the Cannots responded correctly. The Cannots selected the given change as evidence that evolution of living things was taking place, and in effect they gave a Lamarckian interpretation of a structural change of organisms, e.g., caused by occasional absence of wisdom teeth, in contradiction to their responses to question 1. It is noteworthy that the total group and the Cannot group selected this distractor more frequently than any other.

At a more sophisticated level, question 16 asked the students to deal with the development of antibiotic resistant bacteria in terms of statements reflecting Lamarck's and contemporary patterns of explanation --these explanations were not so labelled but were formulated in terms of acquired or inherited characteristics. Only the Can group selected the best answer most frequently, with 61 percent answering this question correctly. The total group and the Cannot group selected a statement reflecting Lamarckian thinking in preference to a statement more consistent with current evidence regarding evolution. Only 34 percent of the total group and 13 percent of the Cannot group selected the best response to this question. Another dimension of the same basic idea appears in the question (which has been previously analyzed)[1] regarding adaptation. Here again, the Cannot group selected a correct statement (17 "b" and 17 "d") rather than the incorrect statement requested.

Questions 13 and 14 deal with the comparison of Darwin's and Lamarck's theories, and presented four instances in which their ideas were parallel and one in which they were not. Of the total group 50 percent responded correctly, and of the Cans 73 percent and the Cannots 29 percent. The most frequently selected distractor was that which related use and disuse as basic to the theory of evolution. In question 14 the statement was made using the word "disuse" and the students were asked to relate the statement most closely to Darwin, Lamarck, and others. This question was very easy for the Cans, in that 95 percent answered it correctly, while 38 percent of the Cannots answered correctly. In both groups the major distractor was "Darwin."

Questions 6, 7, and 9 were concerned with evidence for evolution. (The participating teachers had indicated they would give less emphasis to evidence for evolution in teaching.) Of the total group 56 percent responded to these three questions correctly; 70 percent of the Can group and 35 percent of the Cannot group responded to these three questions correctly. Designed to test students at their lowest level of understanding, question 6 dealt with fossils and the Cannot group was able to respond correctly 61 percent of its group; on this question theory and assumption again confused some of the Cannot group, with 15 percent of this group responding to each of these two distractors.

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[1] *Supra*, p. 98.

Five questions (1, 2, 5, 13, and 20) may be considered as assessing various aspects of the history of the development of ideas of biological evolution. The mean achievement of all students on this set of questions was 56 percent, of Can students 80 percent and of Cannot students 30 percent. Questions 1 and 20 were the most difficult questions of this set. As has been previously discussed,[1] question 1 asked the students to select a statement which did not describe Lamarck's theory correctly, and the most prominent distractor was a statement which, at the lowest level of difficulty, did describe Lamarck's theory correctly. Question 20 required students to discriminate among facts which were known by most people in Redi's time, to interrelate some aspects of the thinking of his time, and to select the response which was an understanding which Redi believed to be fallacious and which became a basis for his design of the experiment which was described in the test. The pattern of distractors was spread among each of the alternative responses with no single distractor selected predominently by the total group.

Seven questions (4, 6, 7, 8, 9, 10, and 11) dealt with interpretations of evolutionary statements in the context of selected aspects of the nature of science; that is, some of these questions asked whether a particular statement was a theory, an assumption, a fact, etc. The mean achievement for all students was 48 percent, for Can students 67 percent and for Cannot students 30 percent.

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[1] *Supra*, p. 99.

Question 4 required a rather sophisticated level of discrimination between the relative importance of the specific explanatory character of the theory of evolution, and its values over time and its extensibility. The teachers felt that this question might be one which could be best used with differential grading, giving more credit for answer "b," and less for answer "e." This kind of question raises the problem of the degree of discrimination which general education students in biology should be required to achieve.

Questions 6, 7, 8, 9, 10, and 11 were each based on the same set of answers and required students to assign theory, assumption, evidence, and incorrect understanding to a particular statement. Although in each case the Can group did best on these questions, the selection of distractors followed identical patterns for the total group, the Cans and the Cannots. Each question showed the difficulty which students had in relating statements to facts or evidence, to theories, or to assumptions.

Questions 3, 4, 18, and 19 were considered as a group of questions which dealt specifically with the nature of science independently of the subject matter being studied at this particular time. Of the total group of students 55 percent were able to deal with these questions correctly, and of the Can group 68 percent and of the Cannot group 39 percent.

Each of the questions which has been discussed was a positive discriminator between the Can and Cannot groups. The ratio of discrimination was at a high of 18.4:1 (Can:Cannot) on question 15 and a low of 1.3:1 on question 19. Detailed data on the Can-Cannot analysis is presented in Table 3.19.

TABLE 3.19

Can-Cannot Analysis of Test 43

N = 684 Can and Cannots each = 27% of N, or = 184

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		P_{BIS}	Difficulty
		N	%	Direction	Ratio		
1 . . .	Can	145	79%	+	3.3:1	0.50	0.51
	Cannot	44	24%				
2 . . .	Can	167	91%	+	2.4:1	.58	.68
	Cannot	69	38%				
3 . . .	Can	161	88%	+	2.4:1	.54	.66
	Cannot	68	37%				
4 . . .	Can	126	68%	+	2.1:1	.36	.49
	Cannot	60	33%				
5 . . .	Can	157	85%	+	2.3:1	.50	.64
	Cannot	68	37%				
6 . . .	Can	175	95%	+	1.6:1	.50	.84
	Cannot	112	61%				
7 . . .	Can	92	50%	+	1.9:1	.26	.39
	Cannot	47	26%				
8 . . .	Can	140	76%	+	3.0:1	.51	.49
	Cannot	46	25%				
9 . . .	Can	121	66%	+	2.9:1	.44	.44
	Cannot	42	23%				
10 . . .	Can	109	59%	+	2.9:1	.40	.35
	Cannot	38	21%				
11 . . .	Can	101	55%	+	3.1:1	.39	.33
	Cannot	33	18%				
12 . . .	Can	172	93%	+	1.5:1	.46	.81
	Cannot	111	60%				

continued next page

TABLE 3.19 continued

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		p_{BIS}	Difficulty
		N	%	Direction	Ratio		
13 . . .	Can	137	74%	+	2.7:1	.37	.51
	Cannot	53	29%				
14 . . .	Can	175	95%	+	2.5:1	.66	.68
	Cannot	70	38%				
15 . . .	Can	147	80%	+	18.4:1	.77	.37
	Cannot	8	4%				
16 . . .	Can	113	61%	+	4.7:1	.51	.34
	Cannot	24	13%				
17 . . .	Can	137	74%	+	3.6:1	.53	.47
	Cannot	38	21%				
18 . . .	Can	123	67%	+	1.5:1	.20	.58
	Cannot	88	48%				
19 . . .	Can	90	49%	+	1.3:1	.12	.46
	Cannot	70	38%				
20 . . .	Can	133	72%	+	3.4:1	0.51	0.48
	Cannot	39	21%				
AVERAGES . . .					3.4:1	0.46	0.52

When interpreting the differential responses of Cans, Cannots, and the Test Group on Test 43, the reader will recall that the students tested were above average on DAT (VR +NA) test scores. Scores for the DAT (VR +NA) of these groups based upon the publisher's percentile conversion tables are shown in Figure 3.3.

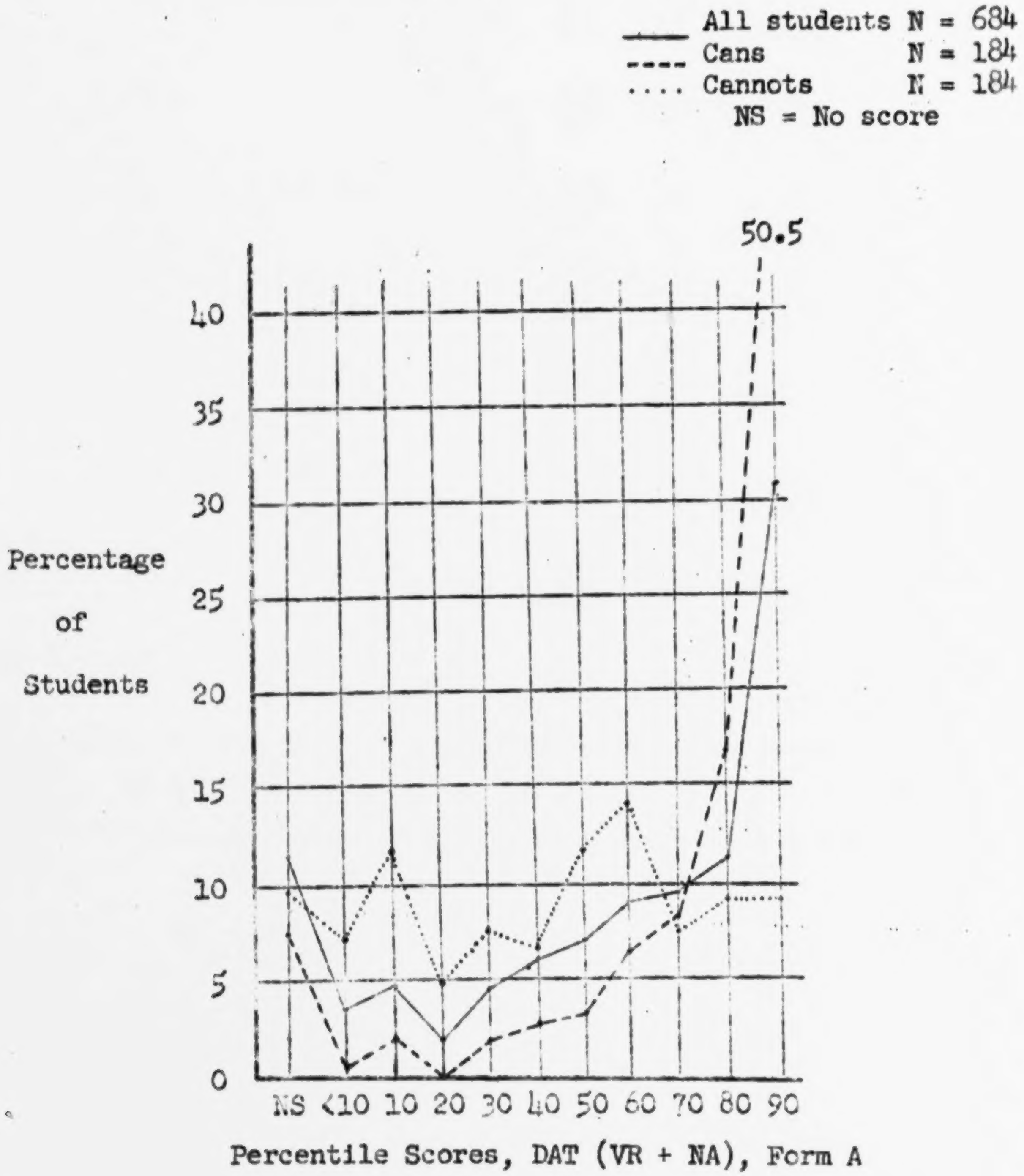


Fig. 3.3.--Frequency distributions for students taking Test 43 by publisher's percentile scores on the DAT (VR + NA).

The median score for the Cans falls at about the 90th percentile, for the Test Group at about the 60th percentile, and for the Cannots at about the 50th percentile.

Test 44, The Chemical Basis of Biology

Development of the Test

The elementary chemistry of biological organisms is included within the development of the heterotroph hypothesis in the BSCS materials. The heterotroph is used as a carrier to introduce chemistry in a novel way and to relate the development and limitations of a contemporary biological hypothesis.

Differences of opinion among the participating teachers as to the emphasis to be given to the heterotroph hypothesis resulted in the development of a test on the chemistry of organisms independent from the heterotroph hypothesis. The test was designed to assess selected aspects of the basic chemical ideas presented in Chapters 5 and 6 of the *Blue Version*.

Two tests from the 1961-62 testing program and a working paper prepared by the project director served as materials for the development of Test 44. The working paper is presented in Table 3.20 in the form in which it was presented to the participating teachers. Corrections and additions added during the discussion appear as underlined statements. Plus signs (+) indicate those items given high priority by the teachers to guide test development and minus signs (-) indicate low priority. Unmarked statements were not to be used as a basis for questions for the core test.

From the recorded group discussion of Table 3.20, the objectives of instruction for the area of study to be assessed by Test 44 may be stated as follows:

TABLE 3.20

Working Paper: The Chemistry of Life

GENERALIZATIONS	Content topics and experiences used in the text and laboratory to develop:	
	products (knowledge and understandings) of science	processes in the growth of scientific knowledge
Materials composing living things can be broken down into elements which are the simplest chemical substances	elements compounds	electrolysis of water as a quantitative means of assessing chemical combination
Elements combine chemically + to produce compounds	atoms molecules	Miller experiment
Compounds ~~of~~ containing carbon and hydrogen are known as organic compounds	chemical bonds	
Elements are composed of like atoms		
Compounds are chemical combinations of two or more elements	Energy exchange in chemical reactions	
Atoms combine to form molecules		
Atoms are held together by + chemical bonds. (Energy is the important idea)		
Amino acids are the basic + building blocks of proteins	amino acids amino group acid group organic "R"	Should know amino acid is a nitrogen containing compound, but it is not necessary to know these terms.
Amino acids link together by + hydrolysis to form proteins	hydrolysis peptide link	- do not use this term - low priority
+ Peptide bonds Elimination of water	polypeptides	- used on three pages of the text and never referred to again.

TABLE 3.20--continued

GENERALIZATIONS	Content topics and experiences used in the text and laboratory to develop:	
	products (knowledge and understandings) of science	processes in the growth of scientific knowledge
The rate of chemical reac- + tion generally doubles for every 10 C rise in temperature (temperature increases chemical reaction)	chemical reaction	
Energy is necessary for syn- + thesis of ~~proteins~~ organic (biological) compounds. Expand beyond protein.		
Coacervates are large mole- - cules which attract water to their surfaces. (Put with heterotroph.)	coacervate cell membrane	preparation and observation of coacervates
Ions are important electric- + ally charged chemical substances	ions negative charges positive charges	
Sunlight and ~~chemical~~ + bonding energy (students would understand this term) are two sources of energy for chemical reactions. (This goes with heterotroph.)		
ATP is a chemical substance + responsible for energy ~~storage-and~~ transfer in living cells. (ATP-ADP cycle gets more attention than this in the text.)	ATP-- chemical structure biological function	

TABLE 3.20--continued

GENERALIZATIONS	Content topics and experiences used in the text and laboratory to develop:	
	products (knowledge and understandings) of science	processes in the growth of scientific knowledge
Materials transfer into and out of cells. (Want idea of things going through and the factors affecting movement. One teacher uses "selectivity of membrane." Someone commented that "selectively permeable" is "fair game" wording.)	cell membrane (permeability)	cell permeability experiment
	- fats	
	+ molecule size	
	+ electrical charge	
	diffusion	diffusion experiment
	+ active transport	
	+ osmosis	osmosis demonstration
Osmosis (the movement of water through a membrane; a kind of diffusion) Osmosis as a process taking place "across" a membrane--"across" not a good wording.		
Fats are important organic - substances found in living things	chemical structure biological function	
Carbohydrates and fats are + primary energy sources in living cells. (But not chemical structures--long chain idea okay for carbohydrates.)	chemical structure of carbohydrates	
Chemical reactions in living + forms are nearly all regulated by enzymes	Requirement for enzyme activity: temperature vitamins acidity	experiment with catylase

TABLE 3.20--continued

GENERALIZATIONS	Content topics and experiences used in the text and laboratory to develop:	
	products (knowledge and understandings) of science	processes in the growth of scientific knowledge
Fermentation is a process in which small amounts of energy are released without the use of oxygen. (Include in heterotroph hypothesis.)	chemical nature of enzymes	
Fermentation of carbohydrates is accomplished by the enzymes of microorganisms	source of energy in carbohydrates	
Anaerobic metabolism is carried out in the absence of oxygen and releases small amounts of energy	glycolysis and fermentation are examples of anaerobic metabolism	
"Gradient" is to be avoided--comes in about once in the book and is never used again. It is a valuable concept. If the term is used, define it, or use context clues.		

1. To understand selected ideas which have been constructed from chemical and biochemical analyses by scientists regarding unity in the diverse forms of life.

    a. To know that the energy of chemical bonds is the energy used by organisms in maintaining their life processes.

    b. To know the relationships between amino acids, proteins, and living things.

2. To understand the ATP-ADP cycle in a simplified form.

    a. To know the significance of ATP in the energy relations of organisms.

    b. To interpret simplified forms of schematic diagrams of the ATP-ADP cycle.

3. To understand the ways in which molecules and ions move or are transported in living things.

    a. To distinguish diffusion, osmosis, and active transport.

    b. To interpret diagrams, experiments, and descriptions of diffusion, osmosis, and active transport.

The Test

Test 44 consists of 35 questions, 25 questions in Part 1 and 10 questions in Part 3. Part 3 was prepared as an optional part but was given by all teachers in the Test Group. The test will be considered as a 35 question unit.

A grid of the test questions by number, content, and classification as developed in the Taxonomy is shown in Table 3.21 below.

TABLE 3.21

Test Analysis Grid for Test 44

(Using the Taxonomy on the horizontal axis)

CONTENT	1.00 Knowledge			2.00 Comprehension	3.00 Application	4.00 Analysis	
	1.10	1.20	1.30	2.20	3.00	4.10	4.20
Chemistry: elements & compounds	3 5	1					
atoms & molecules	20						
ions	24						
amino acid protein	4	22					17 18 19
Energy Relations: bond energy			2				
ATP	23	5					
ATP-ADP cycle						7	8 9
Diffusion: process	13			6			Pt.3 1-10
osmosis					21		
active transport			14		10		
Enzymes	25						
Science as Inquiry: control							11
hypothesis						12	15
plan experiment							16

Using the terminology developed in the Taxonomy, 37 percent of the questions are classified by the project director as assessing aspects of knowledge (1.00) and 63 percent as assessing understandings and skills at the levels of comprehension and analysis (2.00 and above). A copy of the test as given to the students in the Test Group follows.

TEST TITLE: The Chemical Basis of Biology Part 1 Test Number: 44

DIRECTIONS: Write the test number and title, your name, period, teacher, and date on your answer sheet. Mark the best answer by filling in the bubble exactly as shown in the sample. Use only the special pencil in marking your answer sheet. Erase completely any marks you change. DO NOT MARK ON THIS PAPER.

1. Which of the following substances is a compound?

   a. H^+
   b. H_2SO_4
   c. Cu
   d. H_2

2. The energy which can be used by living things exists as:

   a. the energy of the nucleus of the atom.
   b. the energy that bonds one atom to another.
   c. the energy of motion which all atoms possess.
   d. the energy stored in their molecules in the form of heat.

3. Scientists have been unable to break down copper, nitrogen, mercury, and many other substances into simpler substances. Such simple substances are called:

   a. compounds.
   b. elements.
   c. complex molecules.
   d. simple molecules.

4. When two amino acids combine

   a. they form a carbohydrate.
   b. the amino groups are lost.
   c. water is released.
   d. a large amount of energy is released.

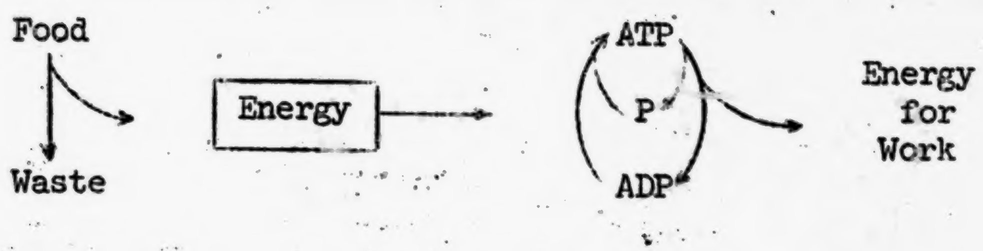
5. Only one of the following is a compound substance:

   a. water.
   b. oxygen.
   c. nitrogen.
   d. hydrogen.
   e. iron.

6. Four of the following influence the rate of entry of particles into cells. (Particles may be ions, molecules, etc.) Which one does not influence the entry of particles into cells?

   a. Size of the particle.
   b. Electrical charge of the particle.
   c. Fat solubility of the particle.
   d. Need for an energy source.

-2-*



Use the above diagram for the next three questions (7 - 9).

7. In the diagram

   a. ATP has more usable energy than ADP.
   b. ADP loses a phosphate and gains energy.
   c. Energy from food is used directly for work.
   d. ATP has less usable energy than ADP.
   e. Waste materials provide a source of energy for work.

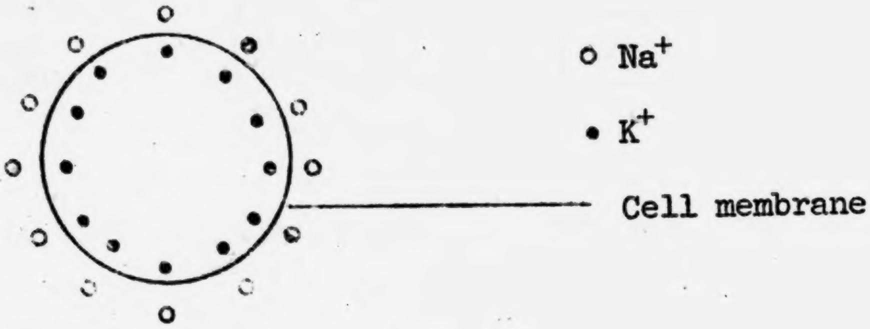
8. One of the following best states the importance to science of the ideas shown in the diagram.

   a. It shows how foods are used by organisms.
   b. It shows that energy for work is obtained from ATP.
   c. It applies to all organisms studied by scientists and indicates the function of ATP.
   d. It applies to processes in living cells.

9. The function of ATP as illustrated in the diagram is,

   a. it stores energy from the working part of the body which it then releases by its breakdown to ADP.
   b. it releases the energy obtained from food by means of a phosphate bond which is a high energy storage bond.
   c. it stores energy from food by means of a phosphate bond and releases this energy as required by the organism.
   d. it transfers energy to ADP which is then released by ADP as required by the organism.

10. If the concentration of ions is maintained as in the following diagram for a long period of time we would assume that:



   a. energy is being expended (used).
   b. energy is being released.
   c. diffusion is occurring.
   d. the cell has died.
   e. energy is not involved in the process.

-3-*

A biologist set up an experiment as follows: a mixture of one-celled organisms was prepared and equal amounts were put in each of three test tubes. A small amount of a black dye was placed in each tube.

Tube 1: A chemical which changes the cell membrane was added.
Tube 2: Was heated to boiling.
Tube 3: Nothing further was done.

Thirty minutes later the one-celled organisms from each tube were examined under the microscope. Observations were as follows:

Tube 1: The black dye was seen in the one-celled organisms and in the fluid surrounding them.
Tube 2: The black dye was seen in the one-celled organisms and in the fluid surrounding them.
Tube 3: No black dye was seen in the one-celled organisms but was seen in the fluid surrounding them.

11. Which of the following statements most correctly describes a part of the experiment?

    a. Tube 1 was the control tube.
    b. Tube 2 was the control tube.
    c. Tube 3 was the control tube.
    d. This was not a controlled experiment.
    e. Tube 1 and 2 were both control tubes.

12. One of the purposes of the experiment described above was:

    a. to test the diffusion of different sized particles through cell membranes.
    b. to test the process of osmosis through cell membranes.
    c. to test the permeability of cell membranes.
    d. to test the active transport of materials through cell membranes.

13. Four of the following statements would be included in a definition of diffusion. Which statement would not be included in a definition of diffusion?

    Atoms, ions, and molecules of any substance in any state . . .

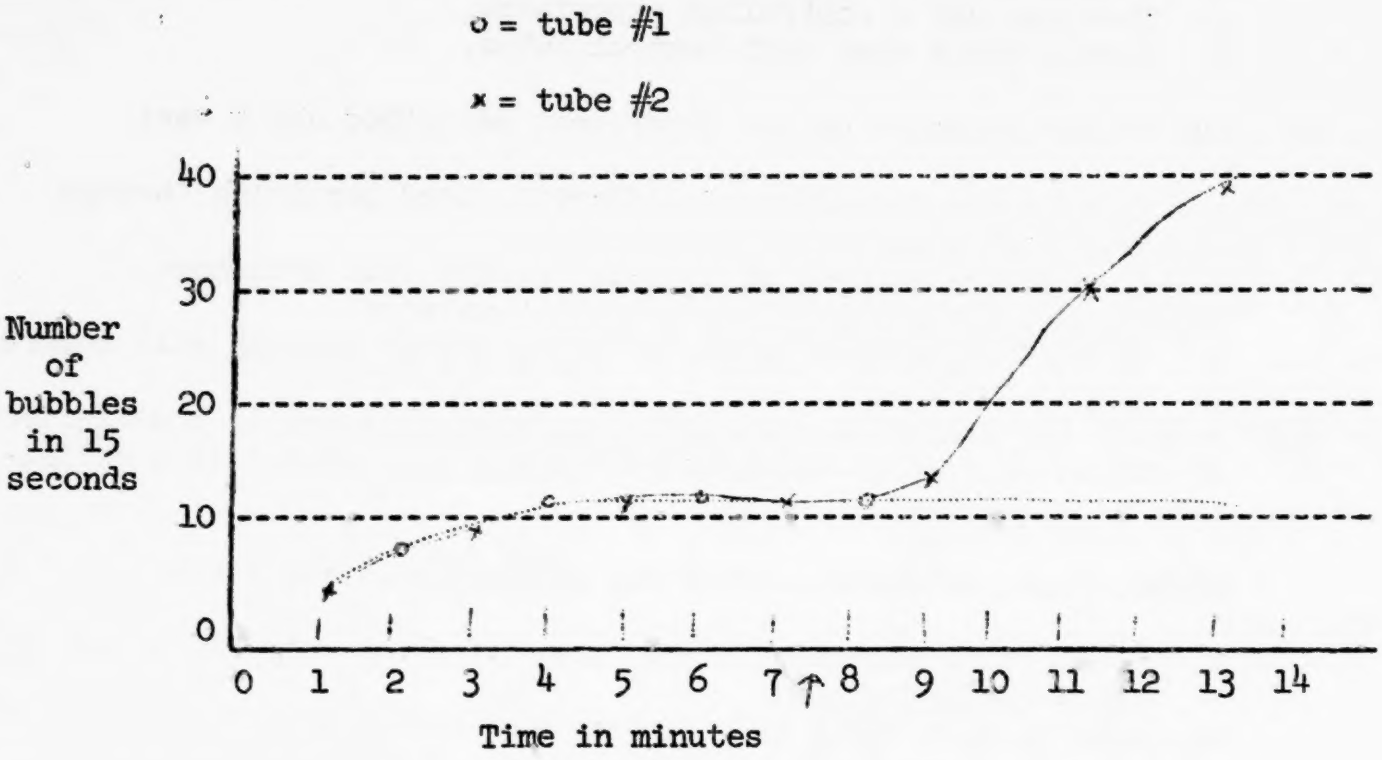
    a. move from a region of higher concentration to a region of lower concentration.
    b. tend to move until they are equally distributed.
    c. move in planned and regular motion.
    d. move in ceaseless motion.
    e. move in random motion.

-4-*

14. Active transport

    a. involves the release of energy.
    b. requires the use of energy.
    c. is called diffusion.
    d. is called osmosis.

A biologist had a hypothesis about a certain chemical "A." In order to test his hypothesis he planned a series of experiments. In the first experiment he used a technique in which the rate of chemical reaction could be determined by counting the number of bubbles of gas produced. He set up two identical test tubes and after the reaction started he counted the number of bubbles for periods of 15 seconds every two minutes. At the point marked (↑) he added a small amount (0.01 gm) of chemical "A" to tube #2. Again he counted the number of bubbles of gas produced for 15 seconds every two minutes in each of the tubes and recorded the data on the graph. All other conditions of the experiment stayed the same.

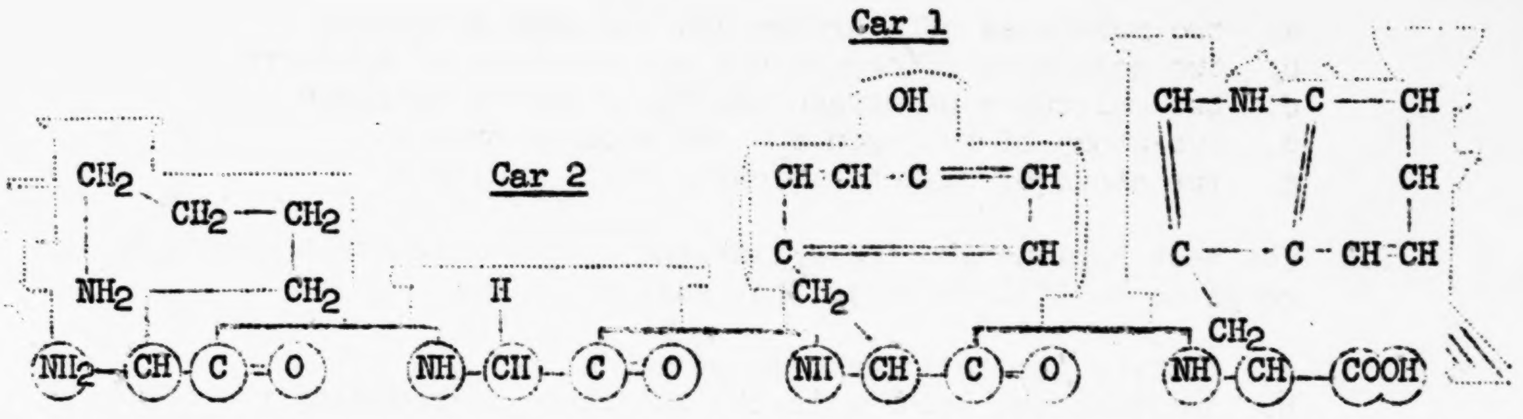


15. From the data recorded on the graph, which of the hypotheses below is the most likely hypothesis being tested?

    a. Chemical "A" may be a vitamin.
    b. Chemical "A" may be ATP.
    c. Chemical "A" may be an amino acid.
    d. Chemical "A" may be a simple sugar.
    e. Chemical "A" may be an enzyme.

16. In order to gather more data to test his hypothesis, which experiment described below would be the best experiment for the biologist to do?

    a. Repeat the above experiment but at 7 minutes add an acid to tube #1 and heat #2 to boiling.
    b. Repeat the above experiment but add 10 times the amount of chemical "A" to tube #1 at the time indicated by the mark (↑).
    c. Repeat the above experiment but heat tube #2 to boiling and cool it before adding chemical "A."
    d. Repeat the above experiment and then at 14 minutes heat both tubes slowly to the boiling point.



The freight train above represents a protein molecule. Refer to the drawing and use understanding of proteins to answer the questions below.

17. In the protein molecule each "car" represents

- a. a simple sugar.
- b. a fatty acid.
- c. a vitamin.
- d. an amino acid.
- e. an ATP molecule.

18. In the protein molecule

- a. energy is stored in the "couplings" connecting one car to the other and not in the "engine."
- b. energy is stored in the "engine."
- c. energy is stored in the "engine" and the "caboose."
- d. energy is stored in the "couplings" and in the "engine."
- e. energy is stored in the "couplings," and "engine," the "caboose," and the "cars."

19. If the "caboose" were moved behind the "engine" and "car 1" were moved to the end of the "train"

- a. the molecule would no longer be a protein.
- b. the molecule would be a protein but it would be a different kind of protein.
- c. the molecule would be the same kind of protein.
- d. the "caboose" cannot be moved from the end position in a protein molecule.

20. The correct description for the formula H_2O is:

    a. two molecules of hydrogen and one atom of oxygen.
    b. two molecules of oxygen and one molecule of hydrogen.
    c. two molecules of oxygen and two atoms of hydrogen.
    d. two atoms of hydrogen and one atom of oxygen.
    e. two atoms of oxygen and one atom of hydrogen.

21. The best explanation for sprinkling concentrated salt solutions on paths to kill weeds is that salt solutions:

    a. destroy the cell membrane of weeds.
    b. increase the acidity in the materials surrounding the cells within the weeds.
    c. cause the vacuole within the cells of the weeds to change their shape.
    d. cause the chloroplasts within the cells to rearrange themselves.
    e. cause the water in the cells of weeds to pass to the outside

22. Amino acids are an important group of chemicals for biologists to learn about because:

    a. they are basic building blocks of proteins.
    b. they are linked together by peptide bonds.
    c. they are composed of elements.
    d. they react with a large number of chemicals.
    e. they are compounds of nitrogen.

23. The energy transfer substance most commonly found in the cells of living things is:

    a. enzyme.
    b. amino acid.
    c. carbohydrate.
    d. fat.
    e. ATP.

24. The cause for the electrical charge of ions is that:

    a. they are always single atoms.
    b. the number of electrons balance the charge of the nucleus.
    c. they are written with a + or - sign to indicate whether they are positively or negatively charged.
    d. the number of electrons does not balance the charge of the nucleus.

25. Chemical reactions in living cells can occur very quickly even at room temperature because of the action of

    a. enzymes.
    b. amino acids.
    c. ATP.
    d. sugars.
    e. ADP.

TEST TITLE: Movement of Substances Through Membranes Part 3*

Test Number: 44

DIRECTIONS: Write the test number and title, your name, period, teacher, and date on your answer sheet. Mark the best answer by filling in the bubble exactly as shown in the sample. Use only the special pencil in marking your answer sheet. Erase completely any marks you change. DO NOT MARK ON THIS PAPER.

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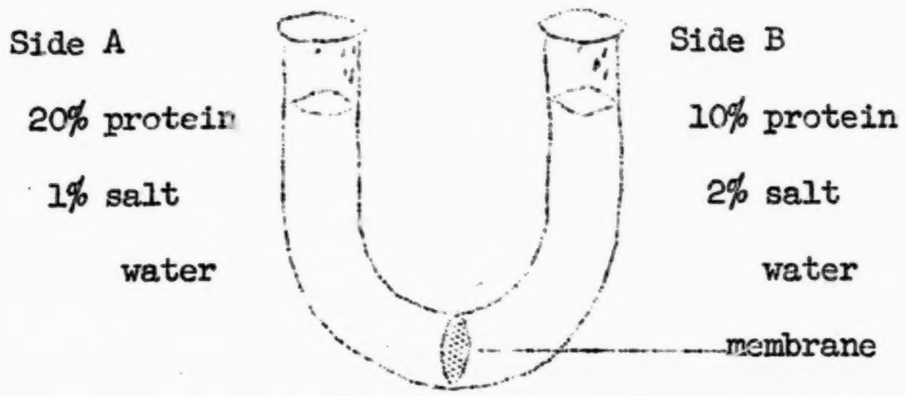
*This question series was modified from a series by Paul L. Drissell and Clarence H. Nelson, Questions and Problems in Science, Test Item Folio No. 1 (Princeton, N. J.: Educational Testing Service, 1956), pp. 6-7.

Part 3

Problem: At the beginning of the experiment the solutions in the two arms of the U-tube are as pictured. They are separated at the bottom by a membrane which will allow water and salt to pass through, but which will not allow the protein to pass through.

Allow the apparatus to stand for a number of days.



Items 1 to 10 refer to the diagram and experiment above. For the items select from the following key the most appropriate phrase.

a. The statement is true and the reason is true.
b. The statement is true but the reason is false.
c. The statement is false but the reason is an accepted fact or principle having no bearing upon the statement.
d. the statement is false and the reason is false.

1. The protein solution on the side B will become less concentrated and that on side A will become more concentrated. The best explanation for this is that a substance tends to diffuse from a less concentrated region to a more concentrated region.

2. The salt solution will become more concentrated on side A and less so on side B. This is best explained by the fact that the salt solution will pass through the membrane from a region of higher concentration of salt to a region of lower concentration of salt.

3. The protein solution will become more concentrated on side A and less so on side B. This is best explained by the fact that the salt solution will pass through the membrane from a region of higher concentration to a region of lower concentration.

4. The water level will rise on side A. The best explanation for this is that the water (not the substance in it) on side A in the beginning of the experiment was less concentrated than that on side B.

5. The protein solution on side A will become less concentrated and that on side B will become more concentrated. The best explanation for this is that water will pass from side B to side A thus diluting side A.

-2-*

(For ease in reading the problem is repeated here.)**

6. The salt solution will become more concentrated on side B and less concentrated on side A. The best explanation for this is that substances tend to diffuse from a region where the water is of lower concentration to one where the water is of higher concentration.

7. There will be no passage of salt through the membrane. The best explanation for this is that only water will pass through the membrane.

8. The passage of water through the membrane in this case is an example of osmosis. Osmosis is defined as the passage of water through a membrane from a region of higher to a region of lower concentration.

9. The water level on side A will rise. The best explanation for this is that water always moves toward a region of higher osmotic pressure.

10. The water level will remain the same in each side. The best explanation for this is that gravity is pulling with the same force on each side.

**Here the problem is stated, diagram shown, and items indicated as on page 1 of test.

TABLE 3.22

Distribution of Correct Scores for Test 44

NUMBER OF CORRECT CHOICES*	BOYS		GIRLS		TOTAL	
	Frequency	Per-centage	Frequency	Per-centage	Frequency	Per-centage
33	. .	. .	2	0.6	2	0.3
32	3	0.9	3	0.9	6	0.9
31	5	1.5	5	1.5	10	1.5
30	3	0.9	2	0.6	5	0.7
29	7	2.1	6	1.8	13	1.9
28	12	3.5	5	1.5	17	2.5
27	10	2.9	5	1.5	15	2.2
26	13	3.8	17	5.0	30	4.4
25	10	2.9	17	5.0	27	4.0
24	16	4.7	13	3.8	29	4.3
23	24	7.1	22	6.5	46	6.8
22	22	6.5	18	5.3	40	5.9
21	27	8.0	12	3.5	39	5.8
20	12	3.5	18	5.3	30	4.4
19	20	5.9	29	8.5	49	7.2
18	24	7.1	31	9.1	55	8.1
17	28	8.3	14	4.1	42	6.2
16	16	4.7	22	6.5	38	5.6
15	9	2.6	18	5.3	27	4.0
14	12	3.5	20	5.9	32	4.7
13	13	3.8	19	5.6	32	4.7
12	12	3.5	6	1.8	18	2.7
11	8	2.4	11	3.2	19	2.8
10	8	2.4	6	1.8	14	2.1
9	12	3.5	5	1.5	17	2.5
8	7	2.1	4	1.2	11	1.6
7	3	0.9	5	1.5	8	1.2
6	3	0.9	5	1.5	8	1.2
TOTAL	339	99.8	340	100.3	679	100.2

*35 is the maximum number possible.

Comments on Questions by Teacher Participants

Several suggestions were made for corrections on Test 44 prior to its use. The first word in the stem of question 6 was changed from "four" to "three." In question 10 the mimeographing did not clearly indicate the difference between the marks inside and outside the circle. A similar problem occurred with the arrow in question 15.

Following the use of Test 44, changes in the wording of several questions were recommended. The explanation of the experiment in Part 3 caused problems for students, i.e., they questioned the decay of the membrane in the system. The best answer to question 4 (Part 3) was extensively discussed. Answer "b" was selected by the project director as the best answer, but the teacher group considered "a" to be the correct answer for the question from the way in which the idea had been taught by them even though they agreed that the explanation was not "the best explanation."[1] This problem recurred in question 9. In both questions the participants agreed that item analyses might assist in assessing the validity of the question and that changing "the best explanation . . ." to "an explanation . . ." would be a better statement.

Analysis of Test Results

Table 3.22 shows the frequency of correct responses. The mean achievement of the 679 students taking Test 44 was 19.0 raw score points, or 54 percent, and the standard deviation was 5.9 raw score points.

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[1] See pp. 124-5.

When interpreting the differential responses of the students on Test 44, the ability of the students as determined by the DAT (VR + NA) is an important variable. Percentile scores for the DAT (VR + NA) of the Test Group, Cans, and Cannots based upon the test publisher's percentile conversion tables are shown in Figure 3.4.

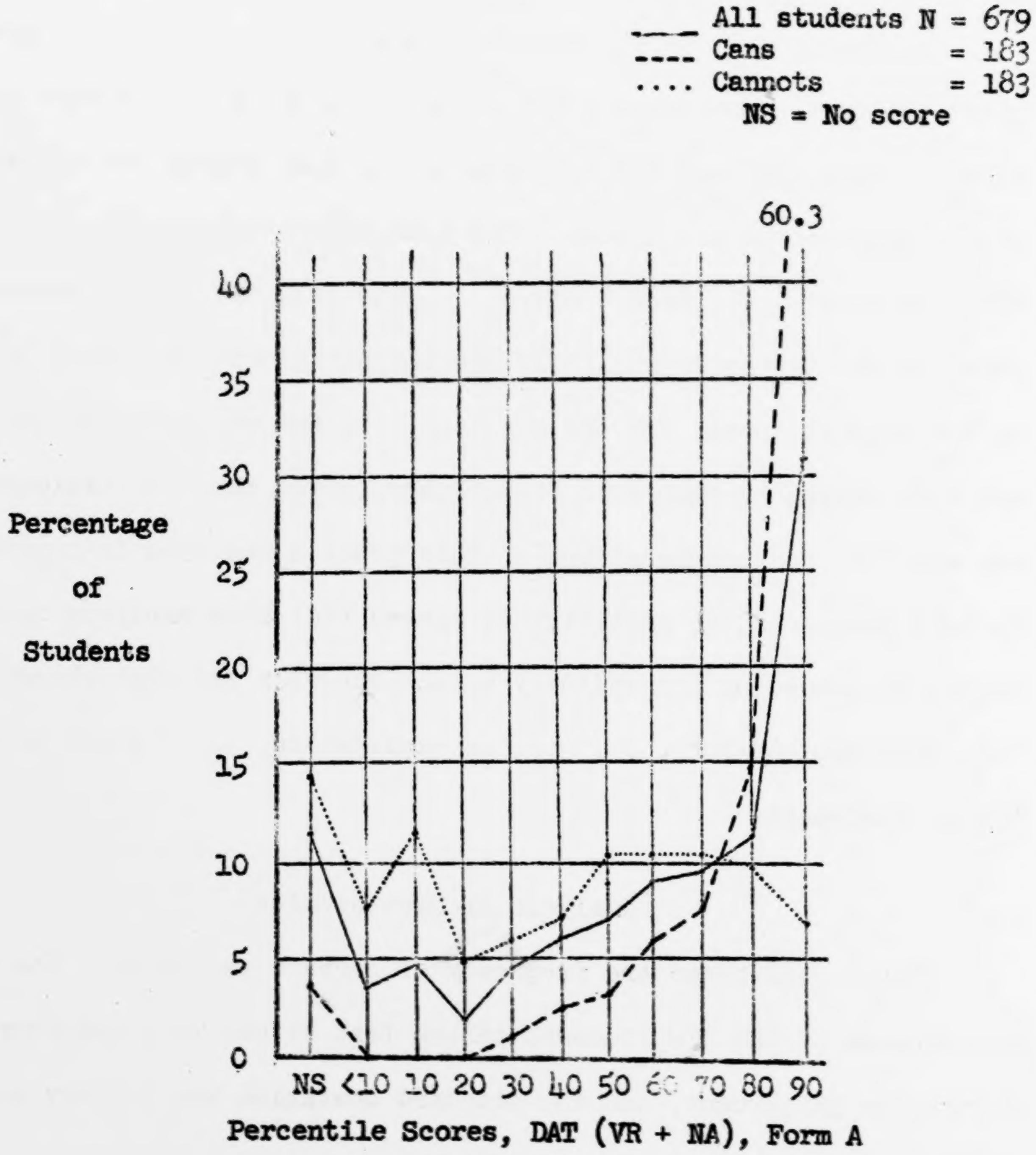

Fig. 3.4.--Frequency distributions for students taking Test 44 by publisher's percentile scores on the DAT (VR + NA).

The median score for the Cans falls above the 90th percentile, for the Test Group at about the 60th percentile, and for the Cannots at about the 40th percentile.

The mean biserial correlation for the 35 questions was 0.48. Question 16 had a negative discrimination. Questions 9, 16, and 18 had biserial coefficients below 0.30. The item responses of all students taking this test are presented in Table 3.23, and the item responses of the Cans and Cannots are presented in Tables 3.24 and 3.25 respectively. Data for the discussion which follows were drawn from these item response tables.

Analysis of the results of Test 44 may be developed by grouping the questions by areas of emphasis. The first emphasis area to be considered will be the "chemistry of organisms."

			% Correct (N = 679)
Chemistry of Organisms 28%	14% Elementary Chemistry	Q. 1	88%
		Q. 3	80%
		Q. 5	80%
		Q.20	79%
		Q.24	62%
	14% Protein Chemistry	Q. 4	58%
		Q.17	51%
		Q.18	33%
		Q.19	58%
		Q.22	77%
	Mean achievement		65%

Students were more successful on the question series dealing with elementary chemistry than with protein chemistry as assessed by the questions noted above. This relative success is even more striking in comparing the Cans and Cannots. Eighty-five percent of the Cans

TABLE 3.23

Item Responses to the Questions on Test 44: Test Group*

Question Number	a	b	c	d	e	Omit
Part 1						
1	2%	*88%*	2%	6%	. .	1%
2	5%	*57%*	11%	25%	. .	1%
3	5%	*80%*	7%	8%	. .	. .
4	25%	4%	*58%*	12%	. .	1%
5	*80%*	3%	4%	3%	8%	1%
6	12%	7%	15%	*64%*	. .	1%
7	*61%*	15%	10%	10%	2%	1%
8	13%	27%	*38%*	21%	. .	. .
9	23%	21%	*46%*	9%	. .	1%
10	*28%*	8%	18%	24%	19%	3%
11	2%	1%	*80%*	7%	9%	1%
12	10%	22%	*38%*	28%	. .	2%
13	7%	6%	*63%*	9%	13%	1%
14	12%	*65%*	10%	11%	. .	2%
15	7%	13%	20%	12%	*47%*	2%
16	15%	25%	33%	*25%*	. .	2%
17	15%	12%	6%	*51%*	15%	1%
18	36%	13%	12%	6%	33%	1%
19	10%	*58%*	9%	21%	. .	1%
20	12%	5%	1%	*79%*	2%	1%

*Expressed as a percentage of N. N = 679.

—— Correct response.

TABLE 3.23--*continued*

Question Number	a	b	c	d	e	Omit
21	23%	7%	4%	5%	60%	1%
22	77%	8%	5%	8%	1%	1%
23	17%	4%	11%	8%	58%	1%
24	3%	22%	12%	62%	. .	1%
25	68%	8%	14%	4%	5%	1%
Part 3						
1	12%	20%	18%	49%	. .	. .
2	61%	11%	19%	8%	. .	. .
3	13%	21%	25%	40%	. .	1%
4	26%	23%	17%	33%	. .	1%
5	34%	20%	17%	28%	. .	. .
6	12%	18%	20%	49%	. .	1%
7	8%	6%	6%	78%	. .	1%
8	60%	23%	9%	7%	. .	1%
9	14%	36%	23%	26%	. .	1%
10	31%	10%	23%	34%	. .	2%

TABLE 3.24

Item Responses to the Questions on Test 44: Cans*

Question Number	a	b	c	d	e	Omit
Part 1						
1	. .	97%	1%	3%	. .	. .
2	2%	90%	4%	5%	. .	. .
3	1%	94%	1%	4%	. .	. .
4	6%	2%	90%	3%	. .	. .
5	95%	1%	. .	1%	3%	1%
6	1%	2%	6%	91%	1%	. .
7	89%	4%	3%	3%	. .	1%
8	11%	20%	57%	11%	. .	1%
9	18%	23%	54%	4%	. .	1%
10	53%	4%	5%	22%	13%	2%
11	. .	1%	96%	3%	1%	. .
12	4%	13%	68%	15%	. .	1%
13	1%	2%	84%	7%	7%	1%
14	3%	91%	3%	3%	. .	. .
15	4%	5%	6%	8%	77%	1%
16	10%	31%	32%	25%	1%	2%
17	8%	5%	3%	80%	3%	. .
18	54%	2%	2%	3%	40%	. .
19	3%	84%	5%	8%	. .	. .
20	5%	1%	. .	94%	. .	. .

*Expressed as a percentage of N. N = 183.

—— Correct response.

TABLE 3.24--continued

Question Number	a	b	c	d	e	Omit
21	9%	1%	3%	4%	83%	1%
22	98%	1%	1%	1%	. .	1%
23	9%	2%	3%	1%	86%	. .
24	. .	7%	2%	91%	1%	1%
25	93%	1%	6%	. .	. .	. .
Part 3						
1	2%	7%	17%	74%	. .	. .
2	78%	4%	15%	3%	. .	. .
3	8%	40%	19%	32%	. .	1%
4	43%	25%	10%	22%	. .	.
5	56%	17%	9%	18%	. .	. .
6	3%	14%	13%	70%	1%	1%
7	2%	5%	1%	91%	. .	. .
8	77%	15%	6%	2%	1%	. .
9	11%	58%	11%	19%	. .	1%
10	17%	8%	37%	36%	. .	2%

TABLE 3.25

Item Responses to the Questions on Test 44: Cannots*

Question Number	a	b	c	d	e	Omit
Part 1						
1	5%	74%	4%	13%	1%	3%
2	10%	27%	19%	42%	1%	2%
3	13%	59%	16%	11%	. .	1%
4	46%	8%	23%	20%	1%	2%
5	52%	9%	11%	9%	15%	3%
6	25%	17%	22%	32%	1%	3%
7	33%	22%	20%	16%	7%	3%
8	14%	31%	21%	34%	. .	1%
9	26%	19%	39%	14%	. .	2%
10	16%	13%	30%	19%	17%	5%
11	4%	3%	51%	15%	25%	2%
12	17%	31%	14%	36%	1%	2%
13	15%	15%	38%	12%	17%	3%
14	23%	40%	16%	17%	. .	3%
15	12%	17%	30%	16%	21%	3%
16	20%	23%	28%	27%	1%	2%
17	23%	15%	10%	27%	23%	2%
18	19%	23%	23%	8%	25%	2%
19	19%	32%	13%	33%	2%	2%
20	22%	13%	5%	52%	7%	2%

*Expressed as a percentage of N. N = 183.

—— Correct response.

TABLE 3.25--continued

Question Number	a	b	c	d	e	Omit
21	40%	12%	7%	4%	34%	3%
22	46%	15%	13%	19%	5%	2%
23	23%	10%	20%	17%	28%	2%
24	4%	34%	30%	30%	. .	2%
25	40%	14%	24%	9%	10%	2%
Part 3						
1	26%	32%	18%	23%	. .	1%
2	42%	19%	27%	12%	. .	1%
3	16%	15%	33%	34%	. .	2%
4	17%	23%	19%	39%	1%	1%
5	22%	26%	21%	30%	. .	1%
6	22%	26%	23%	26%	1%	2%
7	18%	8%	11%	59%	. .	3%
8	48%	27%	13%	9%	. .	3%
9	15%	22%	30%	31%	1%	2%
10	41%	13%	11%	30%	1%	4%

selected correct responses to this series of ten questions as compared with 41 percent of the Cannots. Only the series on protein chemistry will be discussed in detail.

The particular relations assessed by the five questions on protein chemistry were the relations between amino acids and proteins, the coupling of amino acids in proteins, and the importance of amino acids to organisms. Three of the questions were developed as a series using a "train" analogy of a protein molecule.

Questions 4, 17, and 22 dealt specifically with amino acids. In each of these cases, students related amino acids more closely to carbohydrates or to ATP in question 17 than they did to proteins in their distractor selection.

Questions 17, 18, and 19 were developed to assess what may be termed "levels of understanding." Question 17 was designed as the lowest level of this series which most students would understand, and questions 18 and 19 were designed as two additional dimensions of protein chemistry which fewer students would be expected to understand. Figure 3.5 shows the relative responses of the Cans, Test Group, and Cannots on this series.

The relative success of students with question 19 may be attributed in part to selection from four alternative answers as compared with selection from five for questions 17 and 18. Question 17 deals with specific information and question 18 has a series of responses, all of which were correct, but only one, response "e," was complete. Further study would be needed to clarify the responses to this question series. Diversity of type and unity of pattern--the polypeptide chain--was an an important idea of instruction for which question 19 was designed.

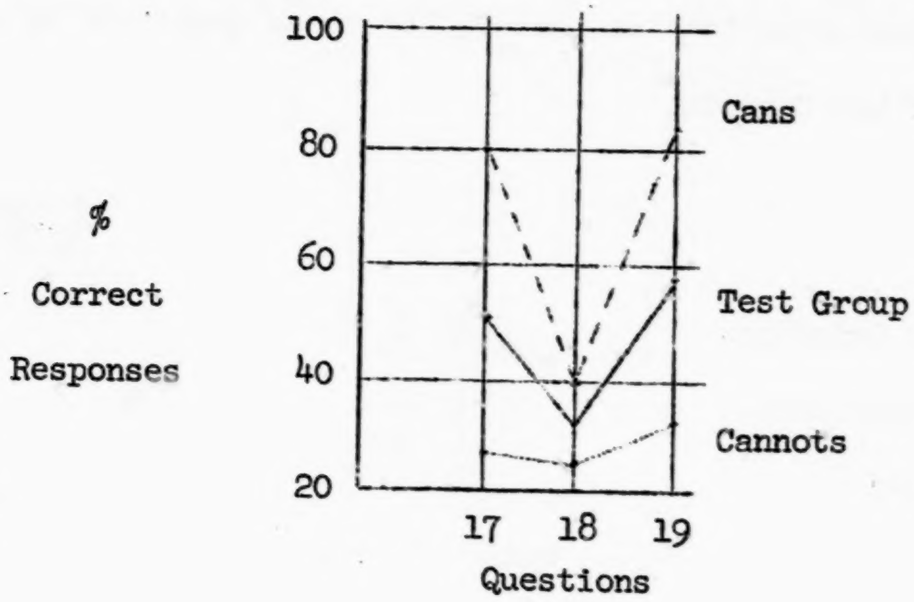

Fig. 3.5.--Percentage of correct responses of three groups on questions assessing selected aspects of protein chemistry.

The Test Group, Cans, and Cannots each selected as the major distractor "d"--that the "caboose" "cannot be moved from the end position in a protein molecule" as the best response; that is, they chose a response which indicated that one could not move a part of a protein molecule. We cannot infer that the students understood that this arrangement was indeed a proposed rearrangement of amino acids, for only 51 percent of the Test Group responded correctly in relating the "caboose" to amino acids in question 17.

The second area of emphasis was developed to assess selected aspects of energy relations in organisms. In contrast with the achievement of the Test Group shown below, 75 percent of the Cans and 29 percent of the Cannots answered this series of questions correctly.

At the lowest level of understanding, question 2 was devised to determine if students understood that chemical bond energy was the source of energy in organisms, and question 23 was devised to assess an understanding of ATP as an energy substance in living things.

Cans understood these relations as measured by these questions by over 3:1 in relation to the Cannots.

		% Correct (N = 679)
Energy Relations in Organisms 14%	Q. 2	57%
	Q. 7	61%
	Q. 8	38%
	Q. 9	46%
	Q.23	52%
	Mean achievement	52%

Questions 7, 8, and 9 were a series based on a diagram of the relationships of food to the ADP-ATP cycle. Figure 3.6 illustrates the relative success of the Test Group, Cans and Cannots for the series.

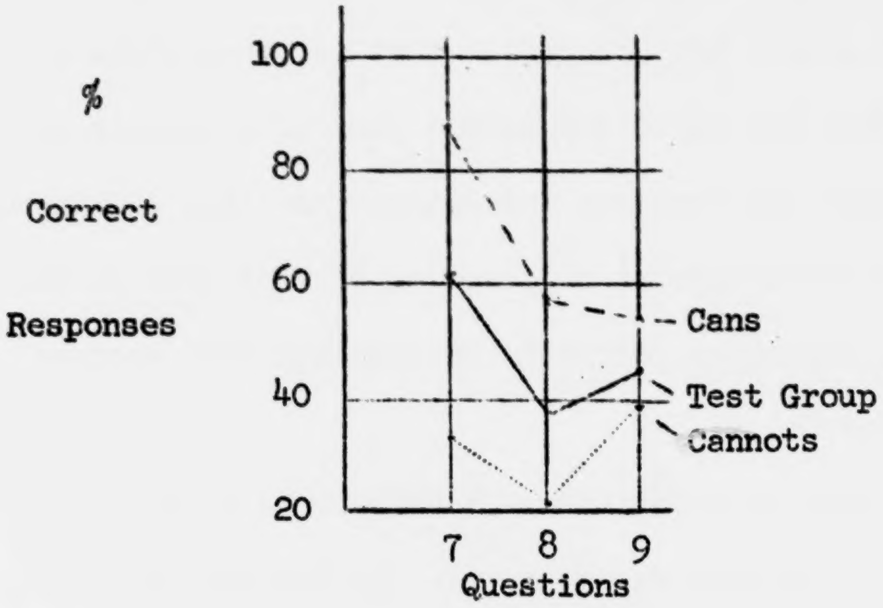

Fig. 3.6.--Percentage of correct responses of three groups on questions assessing selected aspects of the ADP-ATP cycle.

Question 7 was designed to assess the lowest level of understanding and question 9 to determine the students' capabilities to interpret the diagram. The Cans, who missed question 9, selected answer "b," a less complete answer than "c," as the best answer; whereas, those who missed the question in the Test Group and the Cannots selected "a," a partially incorrect answer. Question 8 was the most difficult question of the energy relations series. This question was designed to determine student selections from a series of statements including incomplete reading of the diagram, "a" and "b"; a general statement lacking the precision of the expected response, "d"; and the most precise and inclusive, "c"--this defines the meaning of "best" as used in this question. The order of choices were:

Cans: c, b, a, d;
Cannots: d, b, c, a.

The third emphasis area of Test 44 groups those questions developed to assess aspects of diffusion, osmosis, and active transport.

			% Correct (N = 679)
Movement of Substances in Organisms 43%	6% Diffusion	Q. 6	64%
		Q.13	63%
	6% Active Transport	Q.10	28%
		Q.14	65%
	31% Osmosis	Q.21	60%
		Part 3	44%
	Mean achievement		46%

Question 10 of Part 1, one of the more difficult questions, provides a differentiated distractor selection pattern. The Cans who missed the question selected response "d"--"the cell has died" as their best response; whereas, the Cannots who missed the question selected "c"--"diffusion is occurring"--most often. These responses are considered by the writer to be plausible, but the selection of the Cans is directly contrary to Collander's yeast permeability experiment[1] which the students had performed.

Part 3 of the test consists of 10 statements regarding a written and diagrammed demonstration of osmosis. Questions 3, 4, and 10 were the most difficult for the Test Group, the Cans, and the Cannots, although each discriminated between the Cans and Cannots at a better than 2:1 ratio. In question 3 the students failed to account for the movement of water across the membrane which would change the relative concentration of the non-diffusable protein. Problems with question 4 have been previously mentioned.[2] The teacher participants had discussed "a" and "b" as the best responses but "d" was the most frequently selected distractor for the Test Group and the Cannots. The Cans selected distractors "b" and "d." The differential achievement between Cans and Cannots on question 7 (91 percent to 59 percent correct), a question based directly on reading the problem, raises questions regarding reading skill and/or attention to the test.

On the basis of the data presented, seven of the ten questions would be questionable in terms of the biserial correlations with coefficients between 0.30 and 0.40. These data and the nature of the questions suggest that complexity of statement, the number of variables the student needed to hold, and the degree of required discrimination may have contributed to difficulty. This series raises questions regarding the level of understanding sought by the instructors, and the relative time to teach about osmosis, and the quality of the learning experiences for this student group.

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[1] High School Biology, Blue Version, The Laboratory, Part 1 (University of Colorado, Boulder, Colo.: American Institute of Biological Sciences, Revised Edition, 1961), pp. 103-104.

[2] Supra, p. 127.

The last series of questions to be discussed in Test 44 is a group of questions pertaining to science as inquiry.

			% Correct (N = 679)
Science as Inquiry 11%	3% Identify a Control	Q.11	80%
	6% Identify a Hypothesis	Q.12	38%
		Q.15	47%
	3% Test Hypothesis	Q.16	25%
	Mean achievement		47%

Question 16 was a negative discriminator. An error of omission on the graph may have lead to some confusion on the question. Responses "b" and "c" were each more highly selected responses than "d," the correct response. Seventy-seven percent of the Cans recognized, in question 15, that chemical "a" was an enzyme whereas only 21 percent of the Cannots made this determination. Yet 27 percent of the Cannots chose the best response to question 16 compared to 25 percent of the Cans. It is the writer's opinion that within the pattern of instruction the question was educationally valid. Further investigation is needed to verify this opinion.

Questions 12 and 15 required students to identify purposes or hypotheses in experiments. Both questions produced high discrimination ratios (4.8:1 and 3.6:1) between Cans and Cannots. In these questions a high knowledge component was combined with hypothesis selection.

Thirty-four of the 35 questions on Test 44 were positive discriminators. The detailed data on the Can-Cannot analysis is presented in Table 3.26.

TABLE 3.26

Can-Cannot Analysis of Test 44

N = 679 Cans and Cannots each = 27% of N, or = 183

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		p_{BIS}	Difficulty
		N	%	Direction	Ratio		
Part 1							
1 . . .	Can	177	97%	+	1.3:1	0.46	0.88
	Cannot	135	74%				
2 . . .	Can	164	90%	+	3.3:1	.64	.57
	Cannot	49	27%				
3 . . .	Can	172	94%	+	1.6:1	.49	.80
	Cannot	108	59%				
4 . . .	Can	164	90%	+	3.9:1	.67	.58
	Cannot	42	23%				
5 . . .	Can	174	95%	+	1.8:1	.57	.80
	Cannot	96	52%				
6 . . .	Can	167	91%	+	2.8:1	.62	.64
	Cannot	59	32%				
7 . . .	Can	163	89%	+	2.7:1	.59	.61
	Cannot	60	33%				
8 . . .	Can	104	57%	+	2.7:1	.38	.38
	Cannot	38	21%				
9 . . .	Can	99	54%	+	1.4:1	.15	.46
	Cannot	71	39%				
10 . . .	Can	97	53%	+	3.3:1	.41	.28
	Cannot	29	16%				
11 . . .	Can	175	96%	+	1.9:1	.60	.80
	Cannot	93	51%				
12 . . .	Can	124	68%	+	4.8:1	.56	.38
	Cannot	26	14%				
13 . . .	Can	153	84%	+	2.2:1	.49	.63
	Cannot	70	38%				
14 . . .	Can	166	91%	+	2.3:1	.57	.65
	Cannot	73	40%				
15 . . .	Can	140	77%	+	3.6:1	.56	.47
	Cannot	39	21%				

TABLE 3.26--continued

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		P_{BIS}	Difficulty
		N	%	Direction	Ratio		
16 . . .	Can	46	25%	-	0.9:1	0.01	0.25
	Cannot	49	27%				
17 . . .	Can	147	80%	+	2.9:1	.53	.51
	Cannot	50	27%				
18 . . .	Can	73	40%	+	1.6:1	.17	.33
	Cannot	46	25%				
19 . . .	Can	154	84%	+	2.7:1	.53	.58
	Cannot	58	32%				
20 . . .	Can	172	94%	+	1.8:1	.55	.79
	Cannot	95	52%				
21 . . .	Can	152	83%	+	2.4:1	.50	.60
	Cannot	62	34%				
22 . . .	Can	179	98%	+	2.1:1	.70	.77
	Cannot	84	46%				
23 . . .	Can	157	86%	+	3.1:1	.59	.58
	Cannot	51	28%				
24 . . .	Can	166	91%	+	3.1:1	.64	.62
	Cannot	54	30%				
25 . . .	Can	170	93%	+	2.3:1	.60	.68
	Cannot	73	40%				
Part 3							
1 . . .	Can	135	74%	+	3.1:1	.51	.49
	Cannot	43	23%				
2 . . .	Can	142	78%	+	1.9:1	.38	.61
	Cannot	76	42%				
3 . . .	Can	73	42%	+	2.6:1	.32	.21
	Cannot	28	15%				
4 . . .	Can	78	45%	+	2.4:1	.30	.26
	Cannot	32	17%				
5 . . .	Can	102	56%	+	2.5:1	.36	.34
	Cannot	41	22%				
6 . . .	Can	128	70%	+	2.7:1	.44	.49
	Cannot	48	26%				
7 . . .	Can	167	91%	+	1.5:1	.42	.78
	Cannot	108	59%				
8 . . .	Can	140	77%	+	1.6:1	.31	.60
	Cannot	87	48%				
9 . . .	Can	106	58%	+	2.6:1	.38	.36
	Cannot	40	22%				
10 . . .	Can	68	37%	+	3.2:1	0.35	0.23
	Cannot	21	11%				
AVERAGES, Parts 1 and 3					2.4:1	0.48	0.54

Test 46, The Cell and Photosynthesis

Test 46 was developed to assess the central ideas of chapters 7, 8, and 9 in the text and the accompanying laboratory exercises. The following aspects of these chapters were developed by the participants as areas of emphasis.

1. Complementarity of structure and function of the cell, including the function of the mitochondria.
2. The synthesis of proteins. Protein synthesis should include the relationships among DNA, RNA, ribosomes, enzymes, and proteins.
3. Cell membrane permeability.
4. The function and activities of enzymes.
5. Cell division and mitosis.
6. Photosynthesis.

The processes of cell division and mitosis received extensive discussion because of confusion and contradictions in the use of these terms in the textbook. The group decided that the processes and end results of mitosis, but not the steps of mitosis, are most important; that mitosis is to be considered as the replication of DNA and the division of the chromosomes; that cell division is the total process which includes mitosis and the division of the cells.

The chemical structures involved in photosynthetic pathways were not considered to be as important as the significance of photosynthesis to organisms and the raw materials and end products of photosynthesis.

With these guidelines, the project director developed a series of 35 questions which were reviewed at a subsequent meeting. Following a critique of each of the questions prepared, with revision of the wording of many questions, the teacher participants suggested that a 15 question test on the cell constitute one part of Test 46, and that a 10 question test on photosynthesis be made a second part. With the exception of questions 6, 9, and 15, which were rated by the participants as of secondary importance, all questions in Part 1 were considered to be of first priority. Part 3 of the test was considered to be of lesser importance.

The major objectives of instruction for this area of study were:

1. To complete the development of the heterotroph hypothesis with the evolved cell as this is currently understood, emphasizing the complementarity of structure and function.

2. To develop the replication of DNA and the division of chromosomes as the process of mitosis, and to include mitosis within the larger process of cell division.

3. To briefly develop the nature of photosynthesis as the primary source of energy for all living things, and to stress the process as a conversion of light energy to chemical bond energy.

4. To further develop the nature of enzymes: their functioning and importance in living systems.

The Test

When completed, Test 46 contained four major areas of emphasis: the cell, cell division, photosynthesis, and enzymes. A grid of the test questions by their question number, area of emphasis, and classification as developed in the Taxonomy is shown in Table 3.27 below.

Using the terminology developed in the Taxonomy, 32 percent of the questions are classified by the project director as assessing aspects of knowledge (1.00) and 68 percent as assessing understanding and skills (2.00 and above) at the levels of comprehension and analysis. A copy of the test as given to the students in the Test Group follows.

TABLE 3.27

Test Analysis Grid for Test 46

(Using the Taxonomy on the horizontal axis)

CONTENT	1.00 Knowledge		2.00 Comprehension		3.00 Application	4.00 Analysis
	1.10	1.30	2.10	2.20	3.00	4 20
Part 1						
The Cell: Structure and Function	1 2 3	9				
RNA function			11			
DNA function			4 5			10
Uniformity						13
Cell Division: DNA replication						14 15
Process			6 7		12	
Significance			8			
Part 3						
Photosynthesis: Energy source				4		
End products	6					
Light energy	1			8		
Respiration						10
Enzymes: As catalysts	2					3
Conditions			5			
Relation to Vitamins	9					
Fact and Theory						7

TEST TITLE: The Cell Part 1 Test Number: 46

DIRECTIONS: Write the test number and title, your name, period, teacher, and date on your answer sheet. Mark the best answer by filling in the bubble exactly as shown in the sample. Use only the special pencil in marking your answer sheet. Erase completely any marks you change. DO NOT MARK ON THIS PAPER.

1. The part of the cell which is chiefly responsible for controlling the chemical and physical changes which take place inside the cell is the

   a. cytoplasm.
   b. chloroplast.
   c. nucleus.
   d. ribosome.
   e. vacuole.

2. The outer layer of an animal cell which helps determine which materials enter and leave the cell is the

   a. nucleus.
   b. cell membrane.
   c. mitochondria.
   d. chloroplast.
   e. cell wall.

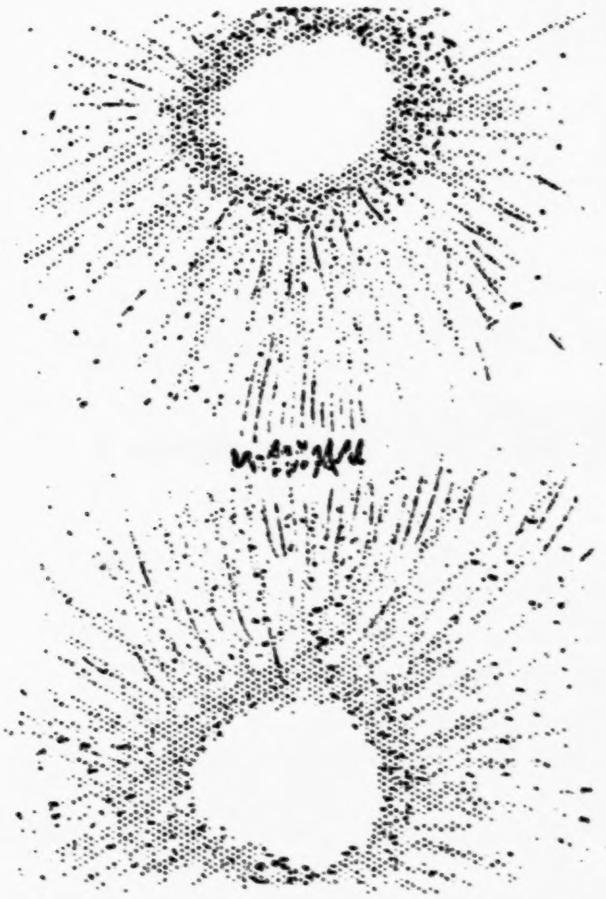
3. In cells the synthesis of proteins from amino acids is done by

   a. nucleus.
   b. DNA.
   c. vacuoles.
   d. ribosomes.
   e. cell membrane.

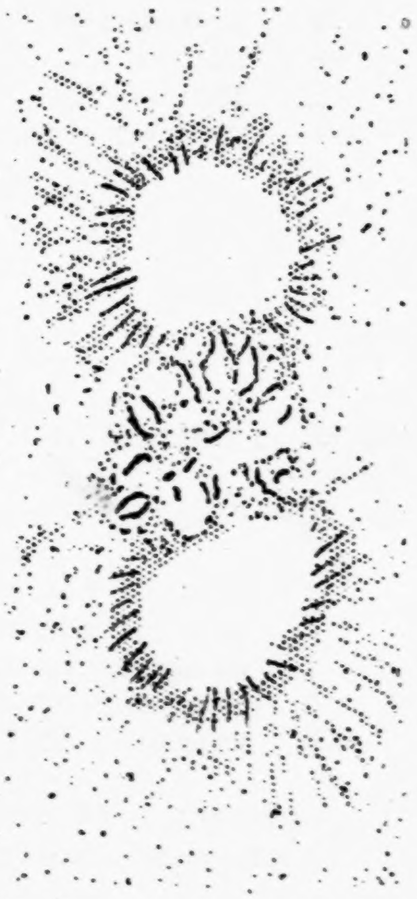
4. An understanding of DNA is important in understanding living things because DNA

   a. serves as an enzyme in all known organisms.
   b. carries the genetic coding from parent to offspring.
   c. is the complex chemical which is essential for life
   d. is found in the nucleus of cells in all known organisms.
   e. is a spiral shaped molecule.

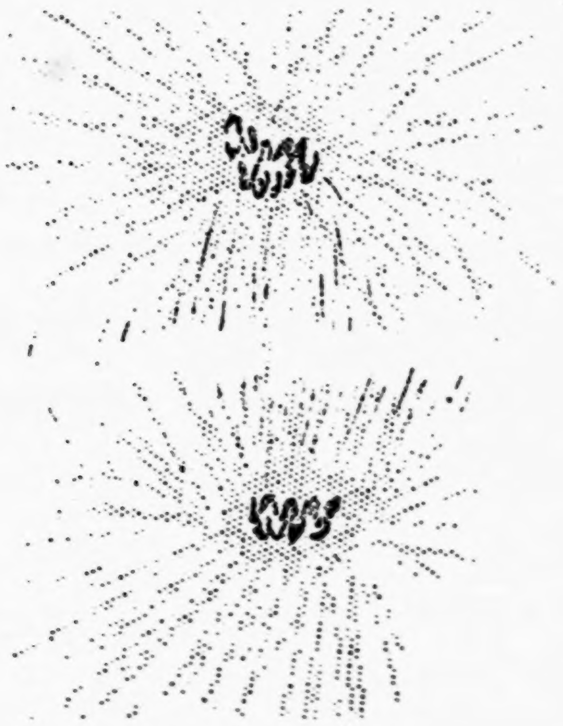
Use the illustrations below for questions number 6, 7, and 8.



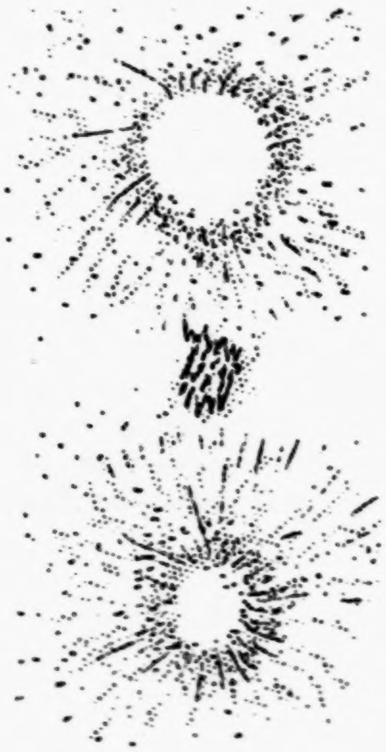
A



B



C



D

5. The pattern of the parts of the RNA molecule is determined by the pattern of

   a. enzymes an organism has.
   b. proteins an organism has.
   c. DNA.
   d. ATP.
   e. food an organism eats.

Use the illustrations preceding this page for questions 6, 7, and 8.

6. The diagram illustrates

   a. part of the Krebs cycle.
   b. part of mitosis.
   c. examples of unicellular organisms.
   d. examples of variations in typical cells.
   e. examples of the replication of DNA.

7. Starting with the first event, the best order of the above photographs would be

   a. B, D, A, C.
   b. D, C, B, A.
   c. C, D, A, B.
   d. A, B, C, D.
   e. They may not be arranged in an order.

8. The significance of the illustrations above to the life of the organism is that

   a. although cells have some parts in common, there are few "typical" cells.
   b. the cell is the basic unit of structure in living organisms.
   c. the nuclear material is duplicated.
   d. energy transfer is accomplished within the constantly changing cell.
   e. none of these.

9. Mitochondria are most closely associated with the enzymes of

   a. digestion.
   b. respiration.
   c. growth regulation.
   d. protein synthesis.
   e. carbohydrate synthesis.

-4-*

10. If the DNA of a living muscle cell were changed by radiation without killing the cell the first effect would be

    a. the interruption of active transport.
    b. in the kinds of proteins the cell could produce.
    c. in the kinds of enzymes the cell could produce.
    d. in the kinds of RNA the cell could produce.
    e. in the kinds of carbohydrates the cell could produce.

11. RNA is an important substance in living cells because it is the substance which influences the kinds of

    a. proteins an organism can make.
    b. carbohydrates an organism can make.
    c. fats an organism can make.
    d. ATP an organism can make.
    e. DNA an organism can make.

12. A cut on the finger kills or injures hundreds or even thousands of cells. The healing processes by which new cells are made are

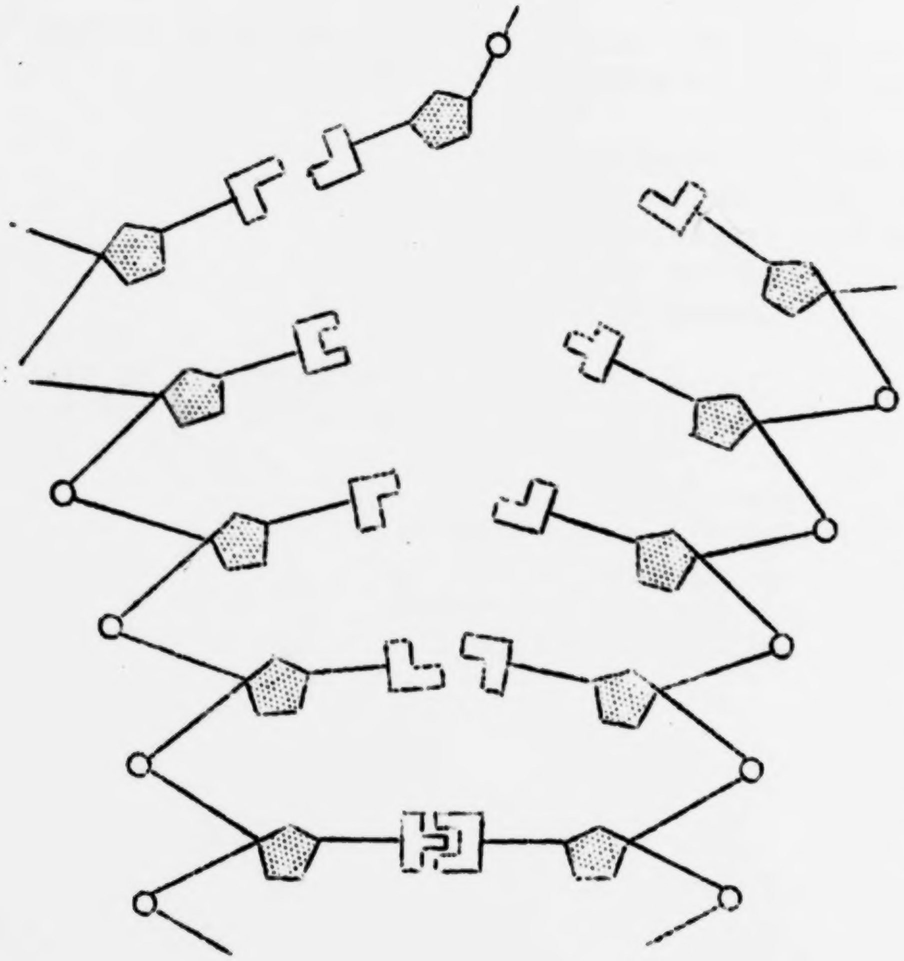
    a. mitosis and respiration.
    b. respiration and photosynthesis.
    c. mitosis and photosynthesis.
    d. respiration and cell division.
    e. mitosis and cell division.

13. If a biologist were able to analyze the chromosomes and DNA in the muscle cells and in the nerve cells of a frog, biological theory would lead us to predict that he would find that the two kinds of cells would have

   a. different chromosome numbers, different amounts of DNA, and a different arrangement of the DNA code.
   b. different chromosome numbers, the same amount of DNA, and the same arrangement of the DNA code.
   c. the same chromosome numbers, the same amount of DNA, and a different arrangement of the DNA code.
   d. the same chromosome number, the same amount of DNA, and the same arrangement of the DNA code.
   e. the same chromosome number, a different amount of DNA, and the same arrangement of the DNA code.

-5-*

Use the diagram below for questions 14 and 15.



14. The drawing is a model of the process by which

    a. materials enter cell membranes.
    b. molecules duplicate themselves as a part of cell division.
    c. nucleic acids form RNA.
    d. energy is released by ATP.
    e. molecules are combined in photosynthesis.

15. The process illustrated above is completed

    a. as the chromosomes move toward the center of the cell when the cell is dividing.
    b. as the chromosomes pull apart as the cell is dividing.
    c. before the chromosomes pull apart as the cell is dividing.
    d. when the chromosomes reach the center of the cell as the cell is dividing.
    e. as the chromosomes break down into chromatin after the cells have divided.

TEST TITLE: Photosynthesis Part 3* Test Number: 46

DIRECTIONS: Write the test number and title, your name, period, teacher, and date on your answer sheet. Mark the best answer by filling in the bubble exactly as shown in the sample. Use only the special pencil in marking your answer sheet. Erase completely any marks you change. DO NOT MARK ON THIS PAPER.

1. In photosynthesis

    a. light energy is changed into chemical bond energy.
    b. chemical bond energy is changed into light energy.
    c. light energy is used as a catalyst.
    d. chemical bond energy is used as a catalyst.
    e. light energy is changed into heat energy.

2. When enzymes are described as catalysts we mean that

    a. they are proteins.
    b. they are produced by living cells.
    c. they change the rate of chemical reactions.
    d. they are used up in chemical reactions.
    e. they are essential to living organisms.

3. Both iron filings and catalase can break down hydrogen peroxide, but catalase is classified as an enzyme and iron filings are not. This must indicate that

   a. iron filings and catalase act as catalysts for only this reaction.
   b. iron filings are inorganic materials and catalase is an organic material.
   c. iron filings will catalize other reactions and catalase will only catalize this one reaction.
   d. iron filings and catalase have a similar molecular pattern.
   e. iron filings and catalase are used up in the reaction.

4. The energy in foods used by living things can be traced all the way back to

   a. light energy.
   b. chemical energy.
   c. heat energy.
   d. mechanical energy.
   e. electrical energy.

-2-*

5. Three conditions necessary for the proper functioning of enzymes are

   a. proper temperature, proper acidity, and living cells.
   b. living cells, proper temperature, and the presence of vitamins.
   c. proper acidity, living cells, and the presence of vitamins.
   d. the presence of vitamins, proper acidity, and the proper temperature.

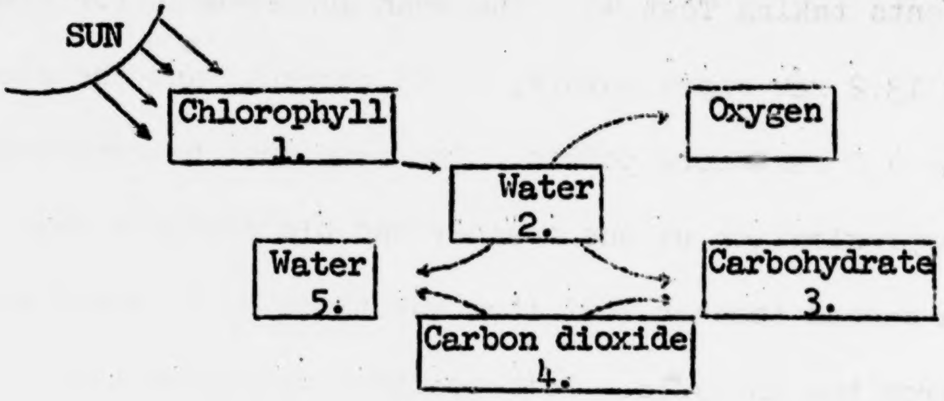
6. The process of photosynthesis always results in the production of

   a. proteins.
   b. carbohydrates.
   c. vitamins.
   d. fats.
   e. oxygen.

7. When light shines on living green leaves of a water plant Elodea bubbles of gas are seen to leave the plant and there is a measureable decrease in the amount of carbon dioxide in the surrounding water. Such facts are significant to the scientist because

   a. facts are the main things scientists deal with.
   b. facts can be interpreted in but one way.
   c. facts collected by scientists "speak for themselves."
   d. facts may be interpreted as giving support to or contradicting scientific theories.

8. The radiant energy of sunlight is captured, converted, and stored in the process by which green plants make food. In the diagram below, which number indicates the location of this stored radiant energy?



a. 1.
b. 2.
c. 3.
d. 4.
e. 5.

9. It is true of vitamins that

a. they may be omitted from human diets because they are part of enzymes.
b. they are necessary for enzymes to become active.
c. they do not become a part of enzyme molecules but assist enzyme action.
d. they are necessary for human health because they correct body acidity.

10. In general plants and animals are similar in that they both

a. change light energy into the chemical bond energy of carbohydrates.
b. release the chemical bond energy of carbohydrates and use up atmospheric oxygen in the process.
c. are able to trap light energy in building carbohydrates.
d. require a source of carbon dioxide to build up carbohydrates.

Analysis of Test Results

Table 3.28 shows the frequency of total correct responses for the 673 students taking Test 46. The mean achievement for these students was 13.2 raw score points, or 53 percent, and the standard deviation was 4.0 raw score points. The mean must be considered as only an approximation as one teacher had his students omit question 7 and a second teacher felt that questions 6, 7, and 8 should be omitted from the analysis. Both teachers indicated that indistinct mimeograph reproduction of the diagrams of the cells in mitosis were their reasons for these omissions.

TABLE 3.28

Distribution of Correct Scores for Test 46

NUMBER OF CORRECT CHOICES*	BOYS		GIRLS		TOTAL	
	Frequency	Per-centage	Frequency	Per-centage	Frequency	Per-centage
23	1	0.3	1	0.3	2	0.3
22	3	0.9	8	2.4	11	1.6
21	5	1.5	7	2.1	12	1.8
20	14	4.2	11	3.3	25	3.7
19	13	3.9	10	3.0	23	3.4
18	15	4.5	11	3.3	26	3.9
17	17	5.1	17	5.0	34	5.1
16	16	4.8	27	8.0	43	6.4
15	26	7.8	40	11.8	66	9.8
14	36	10.7	38	11.2	74	11.0
13	40	11.9	31	9.2	71	10.5
12	29	8.6	30	8.9	59	8.8
11	30	8.9	33	9.8	63	9.4
10	24	7.2	21	6.2	45	6.7
9	22	6.6	15	4.4	37	5.5
8	17	5.1	17	5.0	34	5.1
7	8	2.4	9	2.7	17	2.5
6	11	3.3	3	0.9	14	2.1
5	4	1.2	7	2.1	11	1.6
4	3	0.9	2	0.6	5	0.7
3	..	. .	..	. .	..	. .
2	1	0.3	..	. .	1	0.1
TOTALS	335	100.1	338	100.2	673	100.0

*25 is the maximum number possible.

When interpreting the differential responses of the students on Test 46, the ability of the students as determined by the DAT (VR + NA) is an important variable. Percentile scores for the DAT (VR + NA) of the Test Group, Cans, and Cannots based upon the test publisher's percentile conversion tables are shown in Figure 3.7.

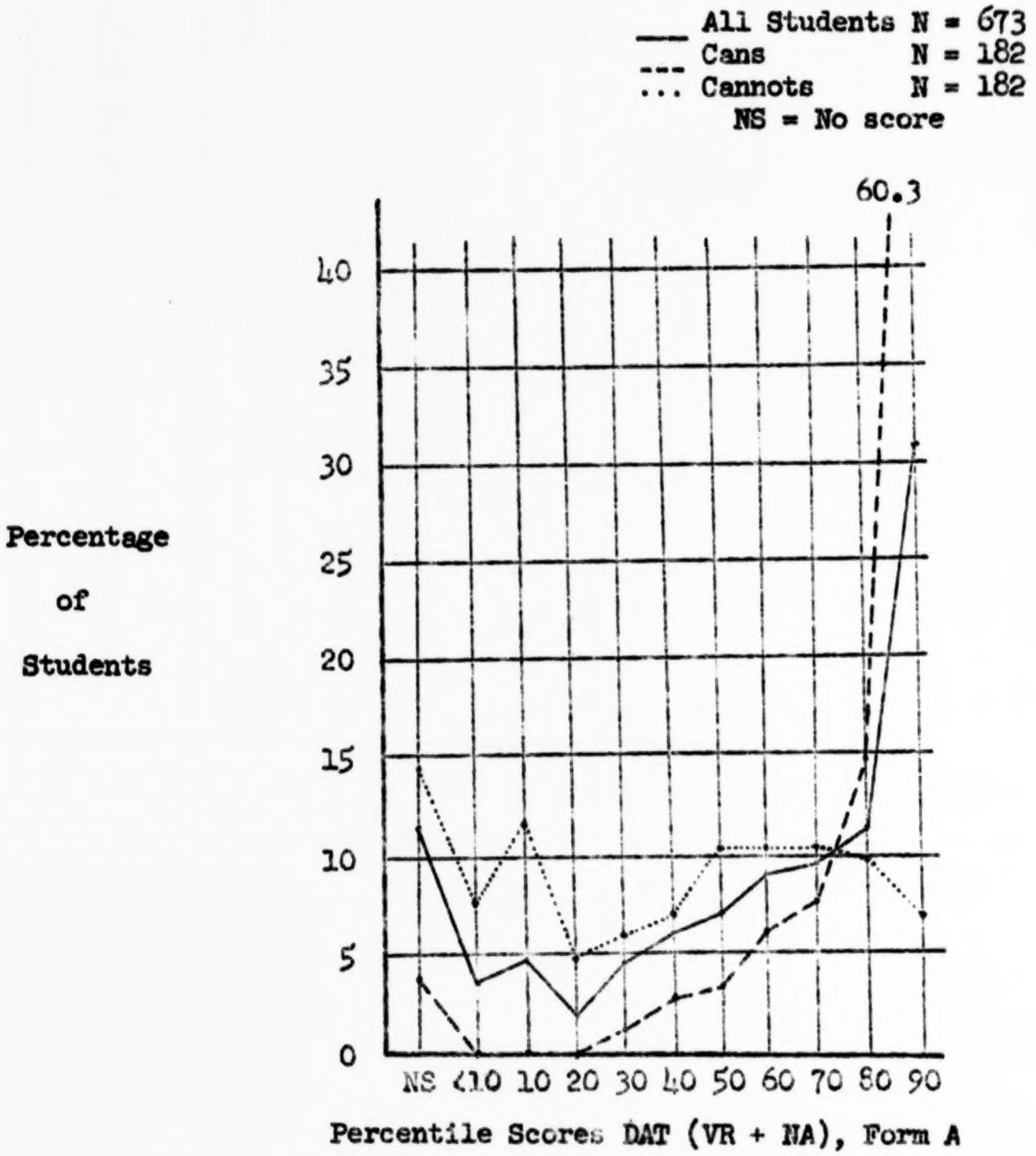


Fig. 3.7.--Frequency distribution for students taking Test 46 by publisher's percentile scores on the DAT (VR + NA).

The median score for the Cans falls above the 90th percentile, for the Test Group at about the 60th percentile, and for the Cannots at about the 50th percentile.

A detailed response pattern of the students taking Test 46 is shown in the item analysis presented in Table 3.29. The item responses for the Cans and the Cannots are presented in Tables 3.30 and 3.31 respectively. Data for the discussion which follows were obtained from these tables.

TABLE 3.29

Item Responses to the Questions on Test 46: Test Group*

Question Number	a	b	c	d	e	Omit
Part 1						
1	8%	3%	82%	6%	1%	. .
2	1%	78%	2%	1%	18%	. .
3	5%	24%	8%	62%	1%	1%
4	6%	61%	14%	18%	1%	. .
5	12%	13%	63%	8%	4%	.
6	6%	77%	3%	5%	9%	. .
7	42%	4%	27%	3%	7%	16%
8	2%	18%	50%	8%	21%	.
9	10%	44%	10%	20%	15%	1%
10	17%	14%	17%	48%	3%	1%
11	55%	11%	6%	10%	18%	1%
12	15%	4%	11%	14%	56%	. .
13	24%	13%	38%	18%	7%	.
14	2%	64%	17%	9%	7%	1%
15	10%	34%	22%	15%	17%	2%
Part 3						
1	67%	8%	16%	2%	6%	1%
2	5%	7%	75%	9%	4%	1%
3	19%	37%	15%	17%	9%	1%
4	57%	16%	8%	12%	6%	1%
5	23%	16%	12%	43%	5%	1%
6	8%	43%	17%	4%	27%	1%
7	8%	5%	20%	66%	1%	1%
8	21%	21%	51%	5%	2%	1%
9	5%	32%	43%	18%	. .	2%
10	14%	50%	10%	24%	. .	2%

*Expressed as a percentage of N. N = 673.

—— Correct response

TABLE 3.30

Item Responses to the Questions on Test 46: Cans*

Question Number	a	b	c	d	e	Omit
Part 1						
1	3%	1%	95%	2%	. .	. .
2	. .	93%	. .	. .	7%	. .
3	4%	3%	3%	89%	. .	1%
4	. .	84%	7%	8%	1%	1%
5	5%	5%	87%	1%	2%	. .
6	4%	94%	1%	. .	2%	. .
7	54%	2%	13%	2%	2%	27%
8	. .	8%	78%	2%	12%	. .
9	4%	68%	2%	9%	17%	. .
10	2%	10%	14%	70%	2%	. .
11	83%	5%	1%	4%	7%	. .
12	13%	1%	5%	10%	71%	. .
13	23%	6%	42%	26%	3%	. .
14	. .	84%	12%	3%	1%	1%
15	5%	26%	44%	9%	15%	1%
Part 3						
1	83%	3%	11%	1%	3%	. .
2	1%	3%	93%	2%	1%	. .
3	16%	45%	19%	16%	4%	. .
4	76%	14%	2%	5%	3%	. .
5	15%	11%	6%	68%	. .	1%
6	1%	72%	3%	1%	23%	. .
7	3%	3%	5%	88%	. .	. .
8	10%	5%	83%	1%	1%	. .
9	3%	54%	35%	7%	1%	2%
10	9%	58%	8%	24%	. .	2%

*Expressed as a percentage of N. N = 182.

—— Correct response.

TABLE 3.31

Item Responses to the Questions on Test 46: Cannots*

Question Number	a	b	c	d	e	Omit
Part 1						
1	15%	8%	64%	10%	3%	. .
2	2%	55%	5%	6%	33%	. .
3	5%	48%	11%	34%	3%	. .
4	15%	31%	21%	30%	2%	1%
5	18%	18%	40%	16%	8%	1%
6	9%	51%	8%	14%	18%	1%
7	24%	7%	44%	4%	15%	7%
8	5%	34%	25%	13%	24%	1%
9	14%	19%	20%	29%	17%	1%
10	34%	18%	19%	25%	3%	. .
11	33%	15%	13%	14%	25%	1%
12	13%	10%	20%	17%	40%	1%
13	30%	20%	29%	10%	9%	1%
14	6%	47%	18%	12%	17%	2%
15	18%	36%	12%	18%	15%	2%
Part 3						
1	49%	13%	22%	3%	12%	2%
2	8%	13%	48%	20%	10%	2%
3	24%	35%	12%	17%	10%	3%
4	39%	19%	15%	15%	10%	2%
5	25%	19%	20%	26%	9%	2%
6	16%	25%	25%	10%	22%	2%
7	11%	10%	33%	43%	1%	3%
8	19%	34%	33%	7%	5%	3%
9	9%	18%	45%	24%	1%	3%
10	18%	40%	18%	19%	1%	4%

*Expressed as a percentage of N. N = 182.

—— Correct response.

Test 46 may be divided into four major sections for purposes of analysis. Nine questions of Part 1 are considered to assess selected aspects of student understandings of the cell.

			% Correct (N = 673)
The Cell 36%	16% Structure and Function	Q. 1	82%
		Q. 2	78%
		Q. 3	62%
		Q. 9	44%
	16% RNA and DNA Function	Q.11	55%
		Q. 4	61%
		Q. 5	63%
		Q.10	48%
	4% Uniformity of Cell Structure	Q.13	18%
	Mean achievement		56%

Students were able to select correct responses for recall questions relating to cell structure and function, although question 9 relating to mitochondrial function was difficult. Nineteen percent of the Cannots and 68 percent of the Cans selected the best response for question 9 as compared with the response of the Test Group shown above. The questions relating to DNA and RNA functions were generally more difficult than the cell function-structure series. Question 13 was the most difficult question for the students of the series on the cell with 26 percent of the Cans and 10 percent of the Cannots answering the question correctly. This question asks students to select a prediction from theory as to muscle and nerve cell contents regarding chromosome numbers, DNA quantity, and DNA code. Distractor "c," "the same chromosome number, the same amount of DNA, and different arrangement of the DNA code," was the most highly selected distractor by the Cans.

The Cannots selected "a" and "c" equally. Distractor "a" stated "different chromosome numbers, different amounts of DNA, and a different arrangement of the DNA code."

Six questions of Part 1 were designed to assess selected aspects of cell division.

			% Correct (N = 673)
Cell Division 24%	12% The Dividing Cell	Q. 6	77%
		Q. 7	42%
		Q. 8	50%
	8% DNA Replication	Q.14	64%
		Q.15	22%
	4% Results of Cell Division	Q.12	56%
	Mean achievement		52%

The most difficult question of this series, question 15, asked the students to place a diagram of DNA replication in a time sequence with respect to chromosome division. Twenty-two percent of the Test Group, 44 percent of the Cans, and 12 percent of the Cannots selected the best response to this question. Thirty-four percent of the Test Group placed DNA replication at the time the chromosomes pulled apart. This same distractor was also the most highly selected by the Cans and the Cannots.

The confusion of the meaning of cell division and mitosis discussed earlier[1] may be evidenced in student responses to question 12. The healing process referred to in this question was related to "mitosis and respiration" by 15 percent of the Test Group, to "respiration and cell division" by 14 percent, and to "mitosis and photosynthesis" by 11 percent. These same distractors were also more highly selected by the Cans and the Cannots.

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[1] _Supra_, pp. 148-9.

Two series of questions were developed to attempt to establish relative "levels of understanding." Questions 6, 7, and 8 of Part 1 referred to illustrations of the process of mitosis. In keeping with BSCS objectives, the names of stages of mitosis were not emphasized, but the ordering of events and the significance of the process were each assessed by questions in this series. Figure 3.8 shows the relative achievement for three groups on this series.[1]

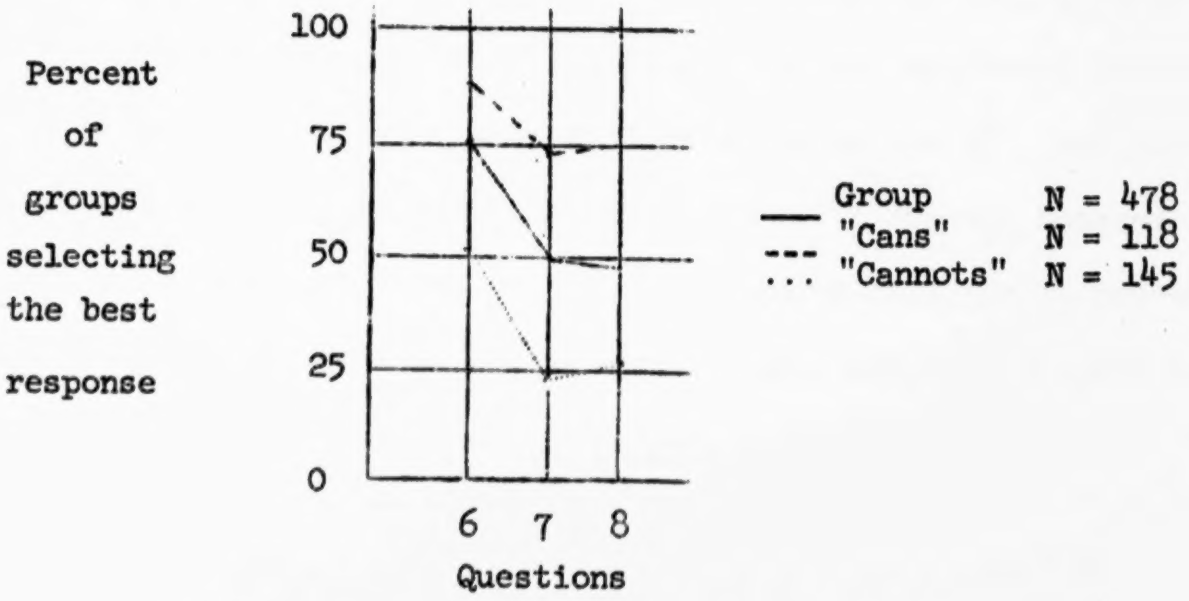

Fig. 3.8.--Frequency of correct responses to a three question series on mitosis.

It was anticipated that nearly all students would be able to recognize diagrams of mitosis and to select the name "mitosis" for the diagrams. Assuming clear diagrams, question 7 required specific understanding of the order of events in mitosis. Only about half of the 478 students[1] were able to select the correct order of these events. Question 8 was equally difficult. The Cannots selected "the cell is the basic unit of structure . . . " and the Cans selected "none of these" as major distractors in preference to "the nuclear material is duplicated" --the best response. The differential achievement between question 6 and 8 was much greater for the Cannots than the Cans.

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[1] The data of two teachers are excluded due to the quality of mimeograph reproduction of the drawings on the tests these teachers used. This resulted in an imbalance in Can and Cannot groups making these data non-comparable with the Cans and Cannots for other questions of this test.

The second series was composed of questions 14 and 15 which were based on a diagram of a model of DNA replication. Recognition of the diagram as DNA and associating this with a part of the cell division process (question 14) was considered to be the more basic of the two questions. It was anticipated that nearly all students would be able to respond correctly to this question. Figure 3.9 shows the relative success of the Test Group, Cans, and Cannots. It should be noted that the diagram used the same pattern as was used in the students' text.[2]

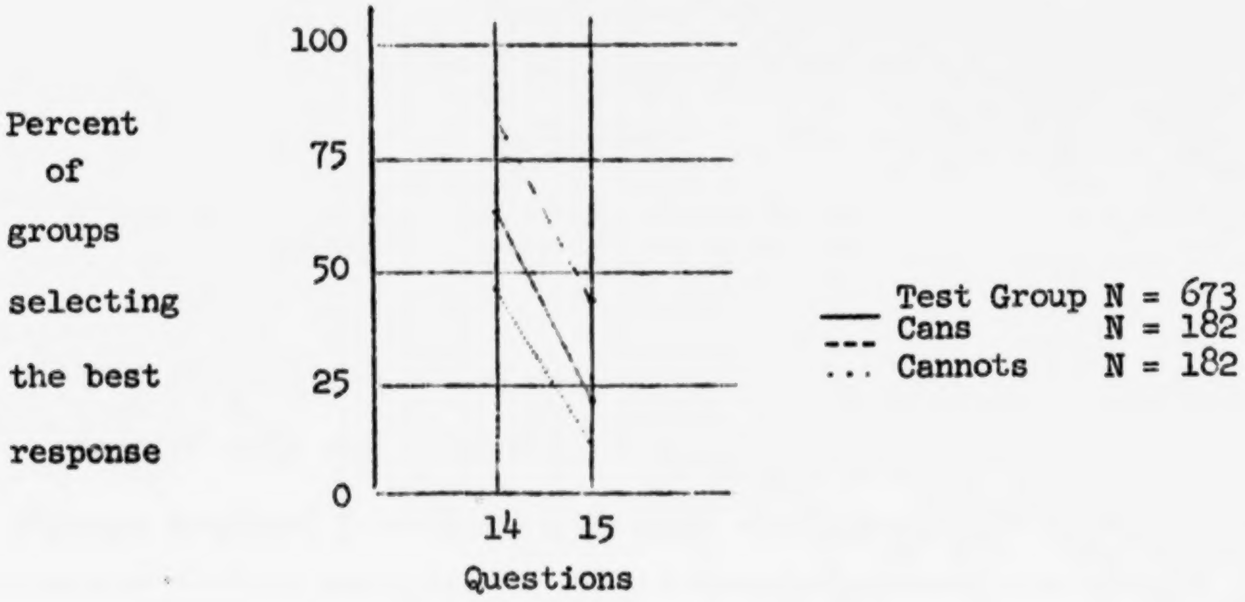

Fig. 3.9.--Frequency distribution of responses to a questions series on DNA.

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[1] This group does not include students from classes of two teachers.

[2] High School Biology, Blue Version, Part 1, Op. cit. p. 150, Fig. 7.7.

The drop in achievement of each group is apparent from the figure above. Recognizing the drawing was not as difficult as relating the event shown to the behavior of chromosomes in a dividing cell.

Five questions in Part 3 were designed to assess selected aspects of photosynthesis.

			% Correct (N = 673)
Photosynthesis 20%	8% and Light	Q. 1	67%
		Q. 4	57%
	8% Results	Q. 6	43%
		Q. 8	51%
	4% and Respiration	Q.10	50%
	Mean achievement		54%

Questions 1 and 4 were designed as minimal level questions. Eighty-three percent of the Cans and 49 percent of the Cannots selected the best response to question 1. Twenty-two percent of the Cannots and 11 percent of the Cans selected "light energy is used as a catalyst" in photosynthesis. In question 4 the major distractor for all groups was to trace food energy "all the way back to chemical energy" rather than to light energy, the best response.

Questions 6 and 8 were designed to assess the students' understandings of aspects of the results of photosynthesis. Seventy-two percent of the Cans selected the best response to question 6 as compared with 25 percent of the Cannots. Twenty-three percent of the Cans and 22 percent of the Cannots selected "e," oxygen, as being always produced in photosynthesis. This distractor was purposefully included because the text devoted considerable attention to photosynthesis in hydrogen sulfide bacteria.[1] The writer developed this question as a probe into the restriction placed on the formation of generalizations through previous learnings. By assuming that many students would have learned in previous science classes, or from the relative emphasis in current instruction, that oxygen was always a by-product of photosynthesis, a probe could be made into this area of understanding. The result of this response pattern suggests that further investigation of this idea may be fruitful.

Students were more successful on question 8 than question 6, but 42 percent of the Test Group selected chlorophyll and water as the location of stored light energy in preference to carbohydrates.

In question 10 the distractors were related to photosynthesis, but the question asked students to select a response which applied to similarities in plants and animals. Fifty percent of the Test Group, 58 percent of the Cans, and 40 percent of the Cannots selected the best response.

Four questions in Part 3 were designed to assess limited aspects of enzymes.

			% Correct (N = 673)
Enzymes 16%	8% Enzymes as Catalysts	Q. 2	75%
		Q. 3	15%
	8% Conditions for Enzyme Function	Q. 5	43%
		Q. 9	32%
	Mean achievement		41%

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[1] Ibid., pp. 167-170.

The distractor pattern for the Cannots on question 2 shows an incorrect statement, "d," selected at a slightly greater rate than a correct, but not "best" response, "b." This same pattern was reflected, but to a lesser extent, in the Test Group. Question 3 was a very difficult question, for only 15 percent of the Test Group, 19 percent of the Cans, and 12 percent of the Cannots selected the best response "c." Response "b" was the most highly selected response by all three groups. Selection of the best response was dependent upon knowledge of the specificity of enzymes as a better distinction between catalysts and enzymes than whether the materials are organic or inorganic. The low biserial correlation is consistent with the low success on the question; however, the validity of the question seems to this writer to remain, for the distinction required for studen success is a valid and expected goal of instruction.

Questions 5 and 9 were designed to assess two aspects of enzyme function. The distractors of question 5 were developed to determine if students, after experimental work with enzymes _in vitro_, considered living cells as a necessary condition for enzyme functioning. From the data above it can be seen that they do. The correct response to this question was the only alternative without "living cell" as a condition for enzyme function. Question 9 included a plausible, but incorrect, response, "d"; two partly correct and partly incorrect statements, "a" and "c"; and the correct response, "b." Eighteen percent of the Cannots, 32 percent of the Test Group, and 58 percent of the ~~Cans~~ selected response "b." Only 7 percent of the Cans, but 18 percent and 24 percent of the Test Group and Cannots, respectively, selected the plausible correct response.

Only question 7 of Part 3 has not been discussed. This question described a photosynthesis experiment as a basis for assessing the significance of facts to scientists. Eighty-eight percent of the Cans, 66 percent of the Test Group, and 43 percent of the Cannots selected the best response "facts may be interpreted as giving support to or contradicting scientific theories." The Cannots and the Test Group selected "facts collected by scientists 'speak for themselves'" as the major distractor.

The mean biserial correlation for the 25 questions was 0.44. All questions were positive discriminators. Eight of the 25 questions had biserial correlations below 0.40 and 3 questions had biserial correlations below 0.30. The ratio of discrimination between Cans and Cannots ranged from 3.8:1 to 1.4:1. Detailed data on the Can-Cannot analysis is presented in Table 3.32.

TABLE 3.32

Can-Cannot Analysis of Test 46

N = 673 Cans and Cannots each = 27% of N, or = 182

QUESTION NUMBER	Frequency on Correct Response			Discrimination		p_{BIS}	Difficulty
		N	%	Direction	Ratio		
Part 1							
1 . . .	Can	172	95%	+	1.5:1	0.48	0.82
	Cannot	115	64%				
2 . . .	Can	170	93%	+	1.7:1	.50	.78
	Cannot	99	55%				
3 . . .	Can	162	89%	+	2.6:1	.58	.62
	Cannot	62	34%				
4 . . .	Can	153	84%	+	2.7:1	.54	.61
	Cannot	57	31%				
5 . . .	Can	159	87%	+	2.2:1	.51	.63
	Cannot	73	40%				
6 . . .	Can	171	94%	+	1.9:1	.55	.77
	Cannot	92	51%				
7 . . .	Can	99	54%	+	2.2:1	.32	.42
	Cannot	44	24%				
8 . . .	Can	142	78%	+	3.2:1	.53	.50
	Cannot	45	25%				
9 . . .	Can	123	68%	+	3.5:1	.50	.44
	Cannot	35	19%				
10 . . .	Can	128	70%	+	2.8:1	.45	.48
	Cannot	46	25%				
11 . . .	Can	151	83%	+	2.5:1	.51	.55
	Cannot	60	33%				
12 . . .	Can	129	71%	+	1.8:1	.32	.56
	Cannot	73	40%				
13 . . .	Can	47	26%	+	2.5:1	.26	.18
	Cannot	19	10%				
14 . . .	Can	152	84%	+	1.8:1	.41	.64
	Cannot	85	47%				
15 . . .	Can	80	44%	+	3.8:1	.58	.22
	Cannot	21	12%				

TABLE 3.32--continued

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		p_{BIS}	Difficulty
		N	%	Direction	Ratio		
Part 3							
1 . . .	Can	151	83%	+	1.7:1	0.38	0.67
	Cannot	89	49%				
2 . . .	Can	170	93%	+	2.0:1	.59	.75
	Cannot	86	48%				
3 . . .	Can	35	19%	+	1.7:1	.12	.15
	Cannot	22	12%				
4 . . .	Can	138	76%	+	1.9:1	.38	.57
	Cannot	71	39%				
5 . . .	Can	123	68%	+	2.6:1	.42	.43
	Cannot	47	26%				
6 . . .	Can	131	72%	+	2.8:1	.47	.43
	Cannot	46	25%				
7 . . .	Can	161	88%	+	2.1:1	.50	.66
	Cannot	78	43%				
8 . . .	Can	151	83%	+	2.6:1	.51	.51
	Cannot	59	33%				
9 . . .	Can	98	54%	+	3.1:1	.39	.32
	Cannot	32	18%				
10 . . .	Can	105	58%	+	1.4:1	0.18	0.50
	Cannot	73	40%				
AVERAGE					2.3:1	0.44	0.53

Test 48, First Semester Final Examination

Development of the Test

Test 48 was developed as a final examination for the first semester of study. By this time of the year the teacher participants were at different points in their teaching of biology but agreed that the semester final should deal with the aspects of biology developed in the text and laboratory materials through chapter 12.[1]

Four major areas were identified by the project director as being central to the first semester of study. These were:

1. The nature of scientific inquiry.
2. The theory of evolution.
3. Cell biology.
4. Multicellular organisms.

This last area was to be concerned only with asexual and sexual reproduction in multicellular organisms. An analysis was made of the relevant content and a form was developed for the selection of priorities for this examination. This form was mailed to the teacher participants in order that they would have an opportunity to rate each generalization in a priority of one (high) through eight (low). The analysis form and the resultant average priority ratings developed from those assigned by the individual teacher ratings and modified through a discussion at a participants' meeting is shown in Table 3.33. In preparation for the development of the final exam, the project director proposed that a maximum of five questions and a minimum of three

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[1] See Appendix A, pp. 341-42.

TABLE 3.33

Analysis Form for Selection of Priorities
For First Semester Final, 1962-63

GENERALIZATIONS	Priority	Content topics and experiences used in the text and lab manual to develop: products (knowledge and understandings) of science	processes in the growth of scientific knowledge
I. Nature of Scientific Inquiry			
1. Theories organize facts, give order and pattern to them, and enable the scientist to predict new facts and relations. They have stood the test of time, cover broad areas of knowledge, and are supported by much evidence.	1	theory assumption fact interpretation	Discussion of interrelation of assumption, fact, and theory in many experiments and historical cases.
2. Theories are based upon selected assumptions. Scientists prefer theories with few assumptions.	4	theory of evolution the cell theory	
3. Hypotheses serve the process of scientific inquiry in guiding experimental designs and generating new hypotheses.	7	heterotroph hypothesis	Identifying, formulating, and testing hypotheses
4. Designing experiments with adequate controls and with identified variables is a major activity of the experimental scientist.	7	control single variable	Experiment with phenol red. Catalase.
5. Data collected by experimentation must be interpreted by the experimenter.	5	interpreting concluding	Different conclusions of Redi and Needham. Similar conclusions of Darwin and Wallace. Different conclusions of Lamarck and Darwin.

TABLE 3.33--continued

GENERALIZATIONS	Priority	Content topics and experiences used in the text and lab manual to develop:	
		products (knowledge and understandings) of science	processes in the growth of scientific knowledge
II. Theory of Evolution			
1. Life has changed through the ages and is still changing.	2	fossil record comparative anatomy phylogenetic relationships variation adaptation natural selection	Changes in our ideas from Aristotle, to Lamarck, Darwin, Wallace, and since knowledge of genetics, DNA.
2. Natural selection is a process which produces organisms which are adapted to their environment.	2	DNA and variation meiosis and variation sexual reproduction and variation	Exercise 9, 11 Exercise 10, 12
3. Our current understanding of the origin of life is inadequate to form a theory but we do find the heterotroph hypothesis useful.	7	heterotroph hypothesis 9 assumptions coacervates primitive atomosphere energy sources	Miller-Urey exp. Exericse 18 Use of knowledge from biochemistry to develop assumptions. Amino acids and their synthesis.
4. Scientists believe that life probably started in a form simpler than a cell because the cell appears to be too complex.	4	cell structure nucleus cytoplasm mitochondria	Energy from chemical bonds.
5. Current data lead scientists to reject the idea of life originating spontaneously under existing conditions.	6	Abiogenesis biogenesis	Van Helmont to Redi to Needham to Spallanzani to Pasteur to Oparin.

TABLE 3.33--continued

GENERALIZATIONS	Priority	Content topics and experiences used in the text and lab manual to develop:	
		products (knowledge and understandings) of science	processes in the growth of scientific knowledge
III. Cell Biology			
1. Proteins, with their constituent amino acids are basic building blocks of cells.	5	amino acids peptide linkage polypeptides	Models of amino acids and peptide linkage.
2. Carbohydrates and fats are primary energy sources in living cells.	8	sugar structure bond energy breakdown of sugar breakdown of fats	Description of energy levels in atoms. Models of carbohydrates and fats
3. ATP is a chemical substance responsible for energy storage and transfer in living cells.	2	high energy phosphate ATP--ADP--ATP	
4. DNA is a chemical substance which contains a code of genetic information and which can duplicate itself exactly.	2	DNA code of 4 nucleotides spiral helix "unzipping"	Watson-Crick model DNA prediction and experimental verification of genetic code.
5. The sources of energy for living things are light energy and chemical energy.	1	photosynthesis chemical bonds	Experiments with light and photosynthesis. Dark reaction.
6. In general, green plants are the major group of organisms which can transform light energy into chemical energy.	3	photosynthesis light energy to bond energy chloroplast function	Absorption spectra of chlorophyll and photosynthetic efficiency.
7. The cell is the basic unit of structure in living things.	2	cell membrane active transport DNA-→ RNA-→ protein synthesis ribosomes diffusion osmosis	Observation of living cells. Experiments with membrane permeability. Diffusion experiments.

TABLE 3.33--continued

GENERALIZATIONS	Priority	Content topics and experiences used in the text and lab manual to develop: products (knowledge and understandings) of science	processes in the growth of scientific knowledge
8. Chemical reactions in living forms are nearly all regulated by enzymes.	2	mitochondria enzyme specificity one gene - one enzyme catalyzing action	Experimentation with rates of reactions and enzyme activity Experiments with enzyme specificity.
9. Cells divide to form new cells by the process of mitosis in which DNA in the chromosomes duplicates itself, bringing about a duplication of the chromosomes in such a way that the two cells formed are alike in DNA and chromosome number.	1	DNA duplication chromosomes mitosis cell division growth and repair	Microscopic examination of dividing cells in a timed sequence coupled with Watson-Crick model of DNA.
IV. Multicellular Organisms			
1. Being multicellular makes possible greater complexity of organisms. Differentiation and specialization of cells allows for greater adaptability of the organism.	4	surface area to volume problems evolution of multicellular organisms	Observation of Volvox. Work of Schleidon and Schwann.
2. Asexual and sexual reproduction are found in both plant and animal forms.	2	sexual reproduction and variation meiosis fertilization	Development of model of meiosis.
3. Sexual reproduction and gamete production by meiosis provide for wide variation in the offspring of a set of parents.	2	asexual vs. sexual reproduction meiosis internal and external fertilization	reproduction

TABLE 3.33--continued

GENERALIZATIONS	Priority	Content topics and experiences used in the text and lab manual to develop:	
		products (knowledge and understandings) of science	processes in the growth of scientific knowledge
4. Sexual reproduction provides a flexibility which enables the species to survive in a changing environment.	3	sexual reproduction variation	
5. Regulation of reproductive cycles in placental mammals involves the interaction of hormones and glands.	6	menstrual cycle pituitary-ovary-uterus relations evolutionary sequence in vertebrate reproduction patterns of embryo maintenance	Description of experiments with reproduction hormones. Comparison of vertebrate groups based on assumptions of evolutionary sequence.

questions be developed for each generalization. With twenty-four generalizations this would have meant the development of a final examination with a possible range of 72 to 120 questions. Since this proposal would have provided equal weight to generalizations which were given different ranks by the participating teachers, it was modified to provide for more weighting for high priority generalizations. Rank 7 and 8 generalizations were eliminated in order to provide for a test with four questions for generalizations rated 1, 2, and 3 and three questions for generalizations rated 4, 5, and 6.

The Test

The final model for development of Test 48, with the number of questions to be developed for each of the four major sections with a topical title of the generalizations included within each question, is presented in Table 3.34. This model proposed a total of 77 questions. Table 3.34 also shows the actual number of questions developed within each of the four areas and the percentage of the test devoted to each of these areas. The completed test contained 65 questions distributed as shown in Table 3.34. The increase in the questions on the nature of scientific inquiry and the decrease in those on the theory of evolution developed because many of the questions which were categorized as being within the theory of evolution were evaluated by the project director as being concerned more with the nature of scientific knowledge than with its special manifestation in evolutionary theory--the shifting of categories being a function of emphasis since scientific inquiry proceeds within the context of subject matter content. To more completely represent the design of the final examination, Figure 3.10 shows the

TABLE 3.34

Model for Development of Test 48

Generalizations	Rank	Questions Planned		Questions Developed	
		Number	Percentage	Number	Percentage
I. Nature of Scientific Inquiry					
Nature of Theory	1	7	9.1%	9	13.8%
Experimental Design	4	0	. .	1	1.5
Interpretation of Data	5	3	3.9	4	6.2
		10	13.0%	14	21.5%
II. Theory of Evolution					
Evolution and Natural Selection	2	8	10.2%	3	4.6%
Origin of Life	4	3	3.9	1	1.5
Spontaneous Generation	6	3	3.9	1	1.5
		14	18.0%	5	7.6%
III. Cell Biology					
The Cell as a Basic Unit	2	8	10.2%	4	6.2%
Proteins and Amino Acids	5	3	3.9	4	6.2
Enzymes	2	4	5.2	7	10.8
Cell Division, Mitosis, Meiosis and DNA	1	8	10.2	6	9.2
ATP and Energy Relations	2	4	5.2	3	4.6
Energy Sources and Photosynthesis	3	8	10.2	8	12.3
		35	44.9%	32	49.3%

TABLE 3.34--continued

Generalizations	Rank	Questions Planned		Questions Developed	
		Number	Percentage	Number	Percentage
IV. Multicellular Organisms					
Differentiation and Size	4	3	3.9%	3	4.6%
Reproduction	2	12	15.6	10	15.4
Regulation	6	3	3.9	1	1.5
		18	23.4%	14	21.5%
TOTALS		77	99.3%	65	99.9%

four areas of emphasis, the generalizations within each of these divisions, and the question numbers and their categorizations according to the Taxonomy as assigned by the project director.

Using the terminology developed in the Taxonomy, 38 percent of the final examination test questions are classified by the project director as assessing aspects of knowledge (1.00) and 62 percent as assessing understandings and skills at the levels of comprehension and analysis, (2.00 and above). It will be noted that many questions in Test 48 have been used in previously discussed tests in the same or slightly modified form. A copy of the test as given to the students in the test group follows.

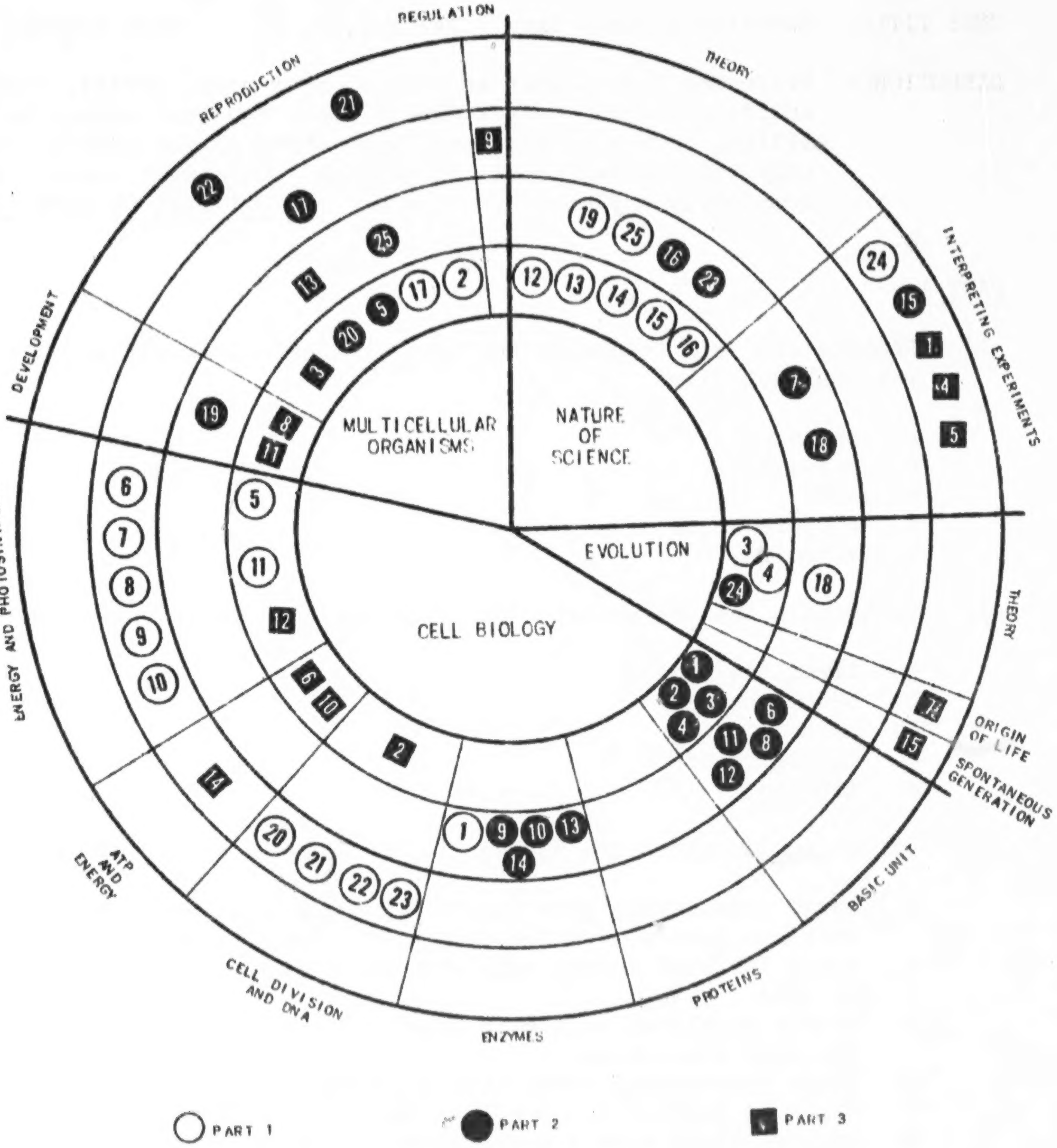


Fig. 3.10.--The distribution of questions on Test 48. The inner circle designates the four major areas of the test and the areas' proportions of the test. The divisions of the major areas represent the proportion of each content area of the test. The concentric rings, beginning with the inner ring, represent categories 1.00, 2.00, 3.00, and 4.00 of the Taxonomy.

TEST TITLE: Semester I Final Exam Parts 1, 2, 3. Test Number: 48

DIRECTIONS: Write the test number and title, your name, period, teacher, and date on your answer sheet. Mark the best answer by filling in the bubble exactly as shown in the sample. Use only the special pencil in marking your answer sheet. Erase completely any marks you change. DO NOT MARK ON THIS PAPER.

PART 1

1. Enzymes are said to change the rate of chemical reactions. In this way they act like

    a. proteins.
    b. catalysts.
    c. ATP.
    d. nucleic acids.
    e. vitamins.

2. Variety in the characteristics of offspring depends primarily on

    a. fertilization.
    b. metamorphosis.
    c. meiosis.
    d. multiplication.
    e. mitosis.

3. Darwin would expect new species to be formed most rapidly in a

    a. large continental area in which geographical and geological features have stayed the same over long periods of time.
    b. small isolated island well stocked with many different forms of life.
    c. thinly populated region in which the conditions for life are the same everywhere.
    d. large continental areas with different geological features which is subject to change in level relative to the ocean.
    e. desert island with a small number of forms of life.

4. Only one of the following does not operate in natural selection:

    a. food supply.
    b. availability of mates.
    c. man's needs and purposes.
    d. inheritable differences.
    e. amount of sunlight.

5. The energy which can be used by living things exists as the energy

   a. in the nucleus of the atom.
   b. of motion of atoms.
   c. that bonds one atom to another.
   d. of the kinds of atoms found in foods.

-2-*

Use the data below in answering questions 6 to 11.

Two test tubes of water, especially prepared, were placed in a test tube rack. A test of the water with phenol red produced a yellow color; a limewater test produced a milky solution. A piece of the green water plant Elodea was placed in one tube and both tubes were placed in strong light. Bubbles were seen to rise from the cut stem of the plant.

6. If a test of the water in the tube with Elodea were made after the rate of gas production had increased and then decreased, a test with phenol red would:

   a. produce a yellow color.
   b. produce a red color.
   c. produce a clear color.
   d. not be helpful in learning about what had happened.

7. If a test of the tube without the Elodea were made at the time of the test with the tube of Elodea, a test with phenol red would:

   a. produce a yellow color.
   b. produce a red color.
   c. produce a clear color.
   d. not be helpful in learning about what had happened.

8. The major biological process which occurred during the production of gas bubbles was

   a. respiration.
   b. photosynthesis.
   c. digestion.
   d. excretion.

9. The source of energy used during the time when gas bubbles were produced was primarily from

   a. sugar molecules.
   b. carbon dioxide molecules.
   c. oxygen molecules.
   d. starch molecules.
   e. light.

10. The gas bubbles in the experiment described above were probably

   a. hydrogen.
   b. carbon dioxide.
   c. oxygen.
   d. methane.
   e. nitrogen.

11. The energy used by living things can be traced from one plant or animal to another but the original source of the energy can be traced back to:

   a. light energy.
   b. chemical energy.
   c. mechanical energy.
   d. heat energy.
   e. electrical energy.

-3-*

In answering the following questions, choose the most correct statement from the following key and mark its letter on your answer sheet..

KEY

a. observation
b. hypothesis
c. assumption
d. theory

12. A hypothesis which is supported by predictions which are shown to be valid takes on this word to describe it.

13. Basic points of view which may direct observations and interpretations of data.

14. On the voyage of the Beagle, Darwin noted that " . . . in the Pampean formation great fossil animals covered with armour like that on the existing armadillos . . . "

15. An idea which has served to explain or account for known data such as the unity of life, diversity of life, fossils, cells, etc.

16. In 1843 Darwin thought that species, contrary to almost universal belief, were not static and unchanging but actually did change over long periods of time.

17. Examples of gametes are

    a. ectoderm and endoderm.
    b. ATP and DNA.
    c. zygotes and blastulas.
    d. eggs and sperm.
    e. chromosomes and genes.

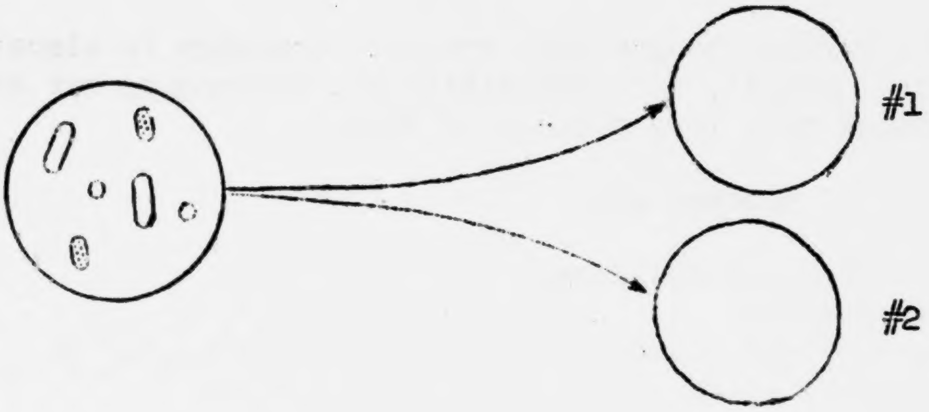
18. Which of the following is the best statement of what evolution means to the biologist?

    a. Change in living forms has occurred in the same way and at the same speed over millions of years.
    b. Living things change; a whole species may alter, and species may die out and others arise.
    c. Plants and animals which lived in the past could not live again.
    d. Because change cannot really be understood, it is best to develop a classification system by which differences can be understood.
    e. Everyone should be concerned about change in living forms.

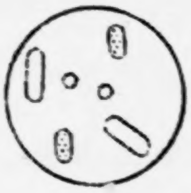
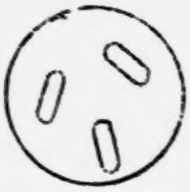
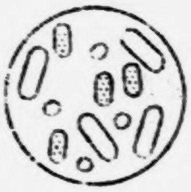
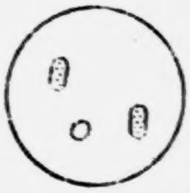
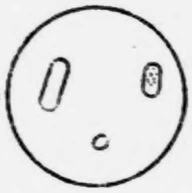
19. In reference to the current knowledge developed by scientists, which statement best characterizes the idea of evolution?

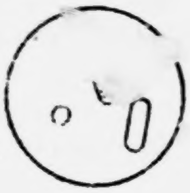
    a. The theory of evolution.
    b. The assumption of evolution.
    c. The hypothesis of evolution.
    d. The process of evolution.
    e. The philosophy of evolution.

The drawing below could represent the general overall process of one cell becoming two cells. Use the drawing in answering questions 20 to 23.



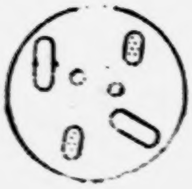
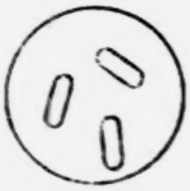
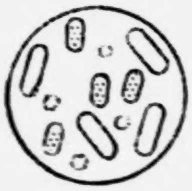
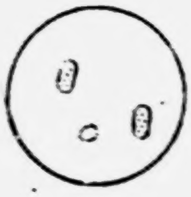
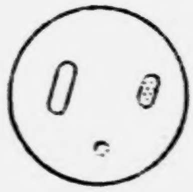
20. If cell #1 and #2 represent reproductive cells they would have chromosomes like

a. 
b. 
c. 
d. 
e. 

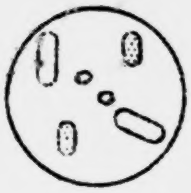
21. If cell #1 had a chromosome pattern like this  it was produced in the process of

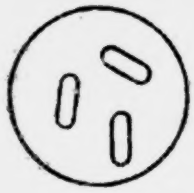
a. mitosis.
b. mutation.
c. osmosis.
d. photosynthesis.
e. meiosis.

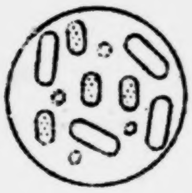
22. If cells #1 and #2 were the result of the division of the fertilized egg they would have chromosomes like

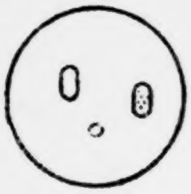
a. 
b. 
c. 
d. 
e. 

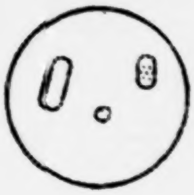
23. If a salamander were repairing a cut leg the new cells (#1 and #2) would have chromosomes like

a.


b.


c.


d.


e.


-5-*

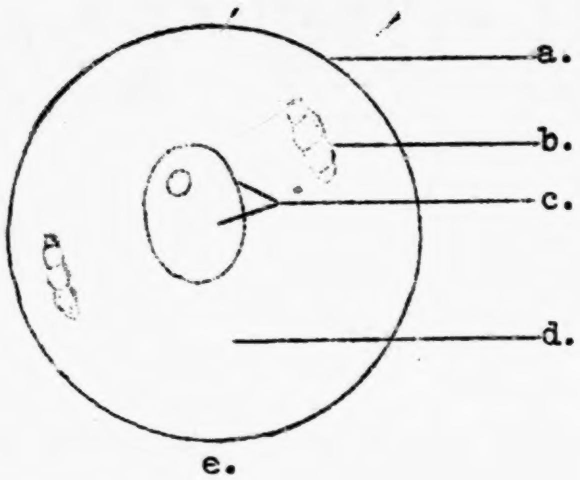
24. When the enzyme diastase is placed in a solution of starch at room temperature tests for the presence of sugar are at first negative, and then, after several minutes greater and greater amounts of sugar are found. Such facts are important to the scientist because:

a. facts can be interpreted in but one way.
b. facts may be interpreted as giving support to or contradicting scientific theories.
c. facts are the main things scientists deal with.
d. facts collected by scientists "speak for themselves."

25. Scientific theories which have the acceptance of a large group of scientists are general ideas which

a. a scientist uses as a way to ask questions of nature.
b. have been proved conclusively and remain unchanged.
c. organize facts, give order and pattern to them, and enable the scientist to predict new facts and relations.
d. a scientist hopes will be supported by evidence.

PART 2



Mark the space corresponding to the one part of the diagram above to which the statement refers. If the statement refers to the total structure, mark answer e.

1. This is the cytoplasm.

2. All parts of the cytoplasm are derived from particles which have passed through this.

3. This is the basic unit of structure and function in multicellular organisms.

4. DNA is found in this structure.

-6-*

5. A nuclear change that is necessary for sexual reproduction is

   a. the development of a new individual from a single cell.
   b. the reduction in the number of chromosomes in gametes.
   c. the development of gametes of different sizes.
   d. the doubling of the chromosome number in gametes.
   e. the development of gametes with the same chromosome number as in the body cells of the species.

In answering the following questions, choose the best statement from the key below and mark its letter on your answer sheet.

KEY

a. Refers to amino acids.
b. Refers to proteins.
c. Refers to enzymes.
d. Refers to nucleic acids.
e. Refers to none of the above.

6. Chemicals which are the basic building blocks of proteins.

7. Have been proved to have existed when life first developed.

8. One type is abbreviated as DNA.

9. Catalase can break down hydrogen peroxide. Catalase would be an example of which of the above?

10. Proper functioning of these requires the presence of vitamins, proper acidity, and proper temperature.

11. An organic molecule with a NH_2 and a COOH attached to the same C atom.

12. They are composed of polypeptides.

13. Each one acts in a specific way in a specific reaction.

14. They act to change the rate of chemical reaction.

15. In 1926 an American biochemist obtained small crystals of a substance from a solution of jack bean flour. A solution of urea without these crystals does not change. If crystals are added, the urea decreases in quantity, new chemicals are found, but the original amount of the crystals can be recovered. These data provide enough information for a scientist to

a. devise tests for the hypothesis that the crystals are enzymes.
b. devise tests for the hypothesis that the crystals are acid.
c. conclude that the crystals are organic.
d. conclude that the crystals are enzymes.
e. conclude that the crystals are acids.

16. From the standpoint of developing theory in biology, DNA is most important in understanding living things because DNA

a. is a spiral shaped molecule made up of nucleotides.
b. is a complex chemical which is necessary for life.
c. is a carrier of genetic coding from parent to offspring.
d. is found in the nucleus of cells in all organisms which have been studied by scientists.
e. is a biocatalyst in all organisms which have been studied by scientists.

17. One species (species A) of single celled animals reproduced by fission and another species (species B) reproduced by gametes. If we assume other characteristics to be similar in the species, with changes in the environment, one would hypothesize that

a. species A and species B would have an equal chance of surviving since the methods of reproduction in simple animals are basically the same.
b. species A would have a better chance of surviving than species B.
c. species B would have a better chance of surviving than species A.
d. neither species would have much chance of surviving since animals become extinct when the environment changes.

18. In an experiment M. C. Niu placed a salt solution in both dish A and dish B. He then placed mesoderm tissue in diash A only, for three hours. He removed the mesoderm tissue from dish A and then placed top ectoderm tissue in both dishes A and B. The most precise (exact) statement of the hypothesis that Niu was testing would be:

a. mesoderm may cause some changes in ectoderm which one will be able to see.
b. ectoderm and mesoderm may both be necessary for cell differentiation.
c. mesoderm may be derived as a distinct tissue from undifferentiated tissues in the embryo.
d. mesoderm may produce a chemical which induces ectoderm to differentiate.
e. ectoderm may produce a chemical which induces mesoderm to differentiate.

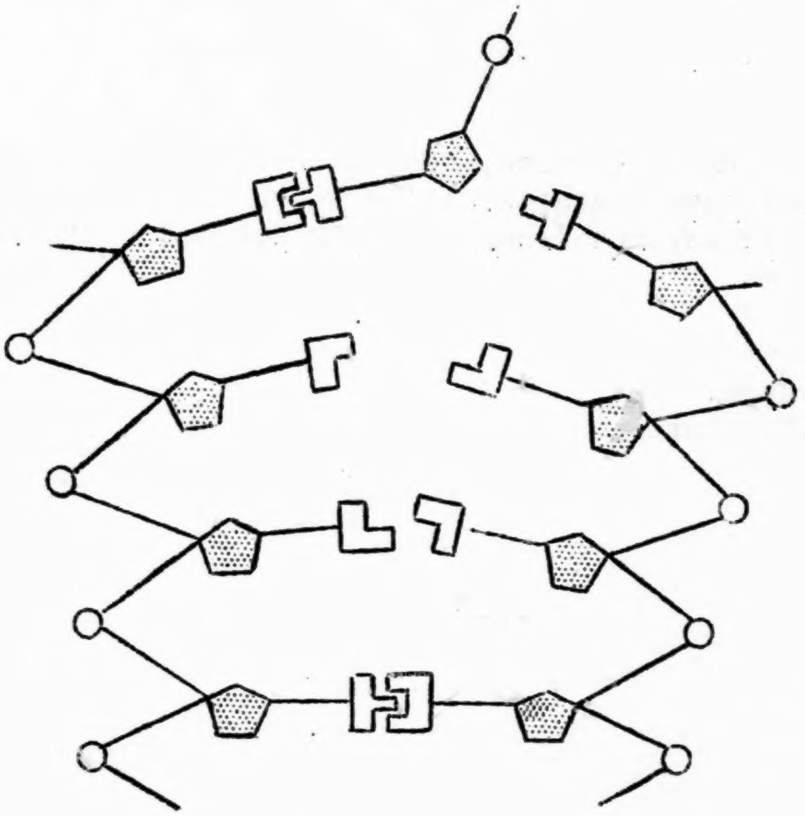
19. In the experiment of Niu described above,

    a. neither tissue grew, nor did either differentiate.
    b. the tissue in both dish A and B differentiated.
    c. both tissues grew but did not differentiate.
    d. the tissue in dish B differentiated, but the tissue in dish A remained the same.
    e. the tissue in dish A differentiated, but the tissue in dish B remained the same.

20. In multicellular organisms, the process of mitosis results in:

    a. growth.
    b. gamete formation.
    c. energy transfer.
    d. zygotes.
    e. fertilization.

Use the diagram below for questions 21 and 22.



21. If the model above is scientifically correct it helps to explain:

    a. how ATP stores and releases energy in living organisms.
    b. what causes ADP to pick up energy and become ATP at a higher energy level.
    c. how DNA is duplicated in an exact manner.
    d. what causes DNA to make a duplicate of itself.

22. If the model above is scientifically correct it leaves unexplained in the process biologists created the model to explain:

    a. how ATP stores and releases energy in living organisms.
    b. what causes ADP to pick up energy and become ATP at a higher energy level.
    c. how DNA is duplicated in an exact manner.
    d. what causes DNA to make a duplicate of itself.

23. Four of the following are accurate statements about theory. Which one is not an accurate statement about theory?

    a. A theory is frequently revised as new knowledge becomes available.
    b. A theory becomes of greater interest to science as it becomes able to explain more and more.
    c. A theory shows what are the purposes, meanings, and values of life.
    d. A theory is developed to account for a body of knowledge.

24. As a result of natural selection, most members of a species of plant or animal have characteristics which best allow them to live in a particular environment. Such special characteristics are known as

    a. variations.
    b. vestigeal organs.
    c. homologous structures.
    d. adaptations.
    e. mutations.

25. Sexual reproduction is a significant factor in organic evolution primarily because it

a. provides for the production of genes.
b. provides the only means for the continuation of any species.
c. provides for variation in offspring of a set of parents.
d. provides for changes in the way in which DNA duplicates itself.
e. provides for offspring which are exact duplicates of a set of parents.

PART 3

A biologist split some cells apart and sorted the pieces into two groups. One group was made up of pieces with a nucleus in each piece, and the other group was made up of pieces without nuclei. He counted out one hundred pieces from each group and placed them in containers under uniform conditions. He reported the following data:

Number of pieces without nuclei studied -------------- 100
Number of pieces without nuclei living one day ------- 80
two days ------ 60
three days ---- 20
four days ----- 0

Number of pieces with nuclei studied ----------------- 100
Number of pieces with nuclei living one day ---------- 79
two days --------- 75
three days ------- 74
four days -------- 70
ten days --------- 67
thirty days ------ 65

1. At the end of this period of time, the biologist was most likely to say:

a. Our data indicate that the nucleus is normally necessary for the continued life of the cell.
b. Our data indicate that pieces with and without nuclei have an equal chance of living.
c. Our data do not allow us to make an interpretation.
d. Our data indicate that a nucleus is not normally necessary for a cell to keep living.
e. Our data indicate that pieces of cells cannot live.

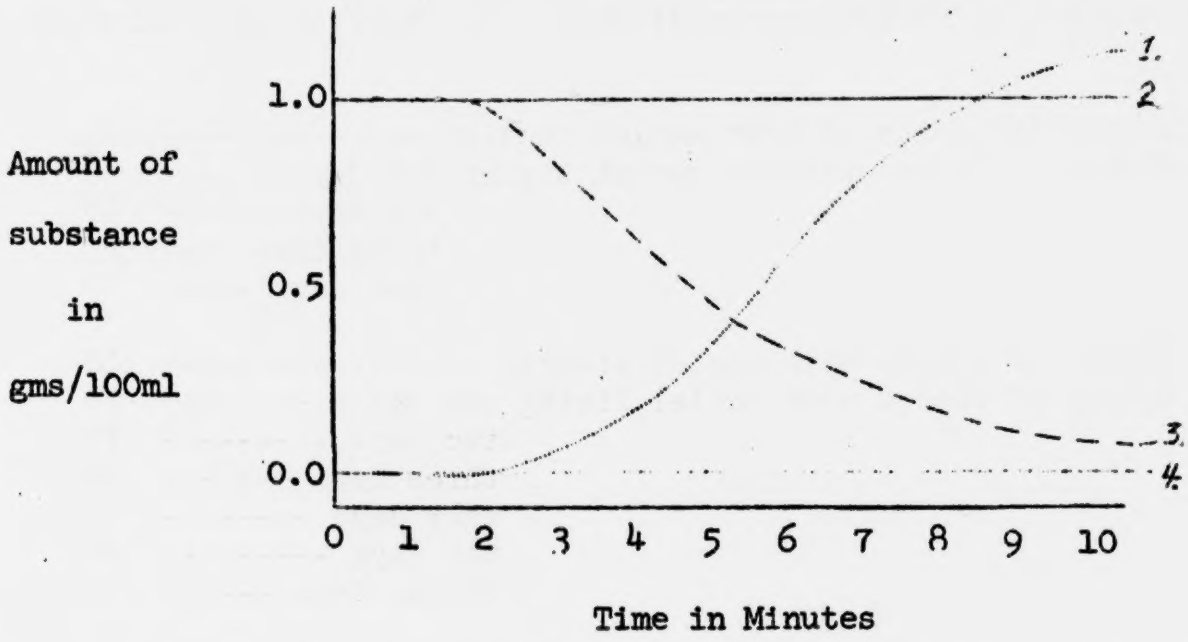
2. The substance which scientists believe is the carrier of hereditary traits in the cell is:

   a. the DNA.
   b. the ATP.
   c. the mitochondria.
   d. the nucleolus.
   e. the ribosmes.

3. the range of normal differences in offspring which a given pair of parents can produce is known to biologists as

   a. mutation.
   b. variation.
   c. adaptation.
   d. speciation.
   e. fertilization.

Urease is an enzyme which affects the breakdown of urea into ammonia. Use the graph below in answering questions 4 and 5.



4. If 0.5 gm. of urease were added at 2 minutes on the graph, which line would best represent the amount of urea?

   a. 1.
   b. 2.
   c. 3.
   d. 4.

5. If the 0.5 gms of urease were heated to boiling in 2 ml of water and then added at 2 minutes on the graph, which line would represent the amount of ammonia?

   a. 1.
   b. 2.
   c. 3.
   d. 4.

-11-*

6. The sequence below which is the most accurate sequence of the movement of energy within the cell is

   a. from a sugar molecule to ATP to energy for work.
   b. from ATP to a sugar molecule to energy for work.
   c. from a sugar molecule to ATP to ADP to energy for work.
   d. from ADP to a sugar molecule to ATP to energy for work.
   e. from a sugar molecule directly to energy for work.

7. The statement "Life began in the form of simple one-celled organisms . . . " is probably

   a. not correct because there are fossils which had many cells.
   b. not correct because of the complexity of cells.
   c. not correct because there is no evidence on the subject.
   d. correct because all living things are made up of cells.
   e. correct because without cells there is no life.

8. By cell differentiation the biologist means that cells become different from each other in:

   a. size.
   b. type.
   c. location in the body.
   d. amount of DNA.
   e. amount of specialized tissue.

9. The chemical substances which most actively regulate the menstrual cycle are produced by

   a. nerves in the reproductive organs.
   b. nerves which connect glands to the reproductive organs.
   c. special cells in the organ which is to be regulated.
   d. glands connected by tubes to the reproductive organs.
   e. glands which release substances into the blood stream.

10. ATP is of great importance to living things because it has

    a. genetic information.
    b. the pattern for synthesizing enzymes.
    c. the pattern for synthesizing hormones.
    d. the pattern for synthesizing proteins.
    e. none of these.

11. The greatest size a cell can become

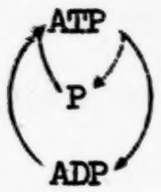
    a. is limited by the amount of food in its environment.
    b. is limited by the relationship of the surface area to the volume.
    c. is limited by the amount of oxygen in its environment.
    d. is limited by the efficiency of the circulatory system around it.
    e. is not limited.

12. The most important group of organisms which convert light energy to chemical energy are

    a. green plants.
    b. organisms which bring about decay.
    c. one-celled organisms.
    d. multicellular organisms.
    e. animals.

13. Sexual reproduction is found

    a. only in man, the flowering plants, and the vertebrate animals.
    b. only in multicellular organisms which have males and females within the species.
    c. only in animals which mate.
    d. in both plants and animals.
    e. in animals but not in plants.



14. The cycle diagrammed above occurs in nature only in

    a. muscle cells.
    b. nerve cells.
    c. living organisms.
    d. animals.
    e. plants.

15. "A piece of meat in a sealed package was left at room temperature for several weeks and did not decay." Select the most scientifically accurate comment from those listed below.

    a. This could not happen because organic materials are not stable: they decay by themselves.
    b. This could not happen because meat will not keep without refrigeration.
    c. This might be possible if the package were air-tight because decay cannot take place without air.
    d. This might be possible if all living organisms in the package were destroyed before it was placed in the room.

Analysis of Test Results

Table 3.35 shows the frequency of total correct responses for the 676 students taking Test 48. The mean achievement for these students was 38.8 raw score points, or 60 percent, and the standard deviation was 10.7 raw score points.

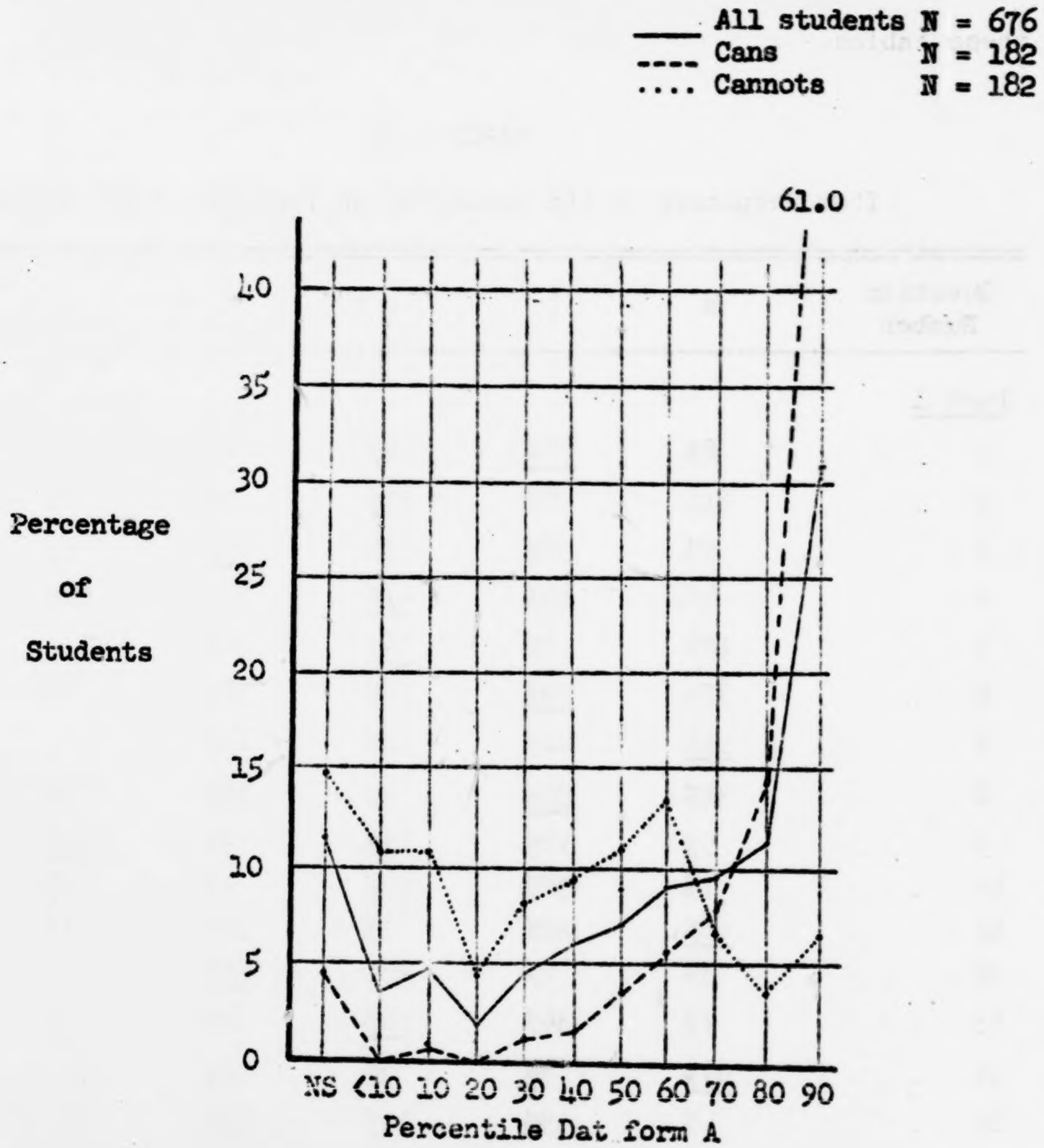
TABLE 3.35

Distribution of Correct Scores for Test 48

NUMBER OF CORRECT CHOICES*	BOYS		GIRLS		TOTAL	
	Frequency	Per-centage	Frequency	Per-centage	Frequency	Per-centage
63-65	..	..	..	..	..	..
60-62	1	0.3	..	..	1	0.1
57-59	9	2.7	9	2.6	18	2.7
54-56	22	6.5	17	5.0	39	5.8
51-53	26	7.7	25	7.4	51	7.5
48-50	31	9.2	24	7.1	55	8.1
45-47	28	8.3	29	8.5	57	8.4
42-44	29	8.6	37	10.9	66	9.8
39-41	41	12.2	30	8.8	71	10.5
36-38	27	8.0	37	10.9	64	9.7
33-35	26	7.7	29	8.5	55	8.1
30-32	25	7.4	27	8.0	52	7.7
27-29	26	7.7	27	8.0	53	7.8
24-26	12	3.6	17	5.0	29	4.3
21-23	15	4.4	13	3.8	28	4.1
18-20	8	2.4	9	2.6	17	2.5
15-17	9	2.7	7	2.1	16	2.4
12-14	2	0.6	2	0.6	4	0.6
9-11	..	..	..	..	..	..
6- 8	..	..	..	..	..	..
3- 5	..	..	..	..	..	..
0- 2	..	..	..	..	..	..
TOTALS	337	100.0	339	99.8	676	100.1

*65 is the maximum number possible.

Percentile scores of the DAT (VR + NA) for the Test Group, Cans, and Cannots are shown in Figure 3.11. The median score for the Cans falls above the 90th percentile, for the Test Group at about the 60th percentile, and for the Cannots at about the 40th percentile.



Percentile Scores, DAT (VR + NA), Form A

Fig. 3.11.--Frequency distributions for students taking Test 48 by publisher's percentile scores on the DAT (VR + NA).

A detailed response pattern of students taking Test 48 is shown in the item analysis presented in Table 3.36, and the item responses for the Cans and Cannots are presented in Tables 3.37 and 3.38 respectively. Data for the discussion which follows were obtained from these tables.

TABLE 3.36

Item Responses to the Questions on Test 48: Test Group*

Question Number	a	b	c	d	e	Omit
Part 1						
1	8%	78%	4%	7%	2%	. .
2	31%	6%	51%	3%	9%	. .
3	6%	36%	5%	50%	2%	1%
4	4%	10%	47%	10%	27%	1%
5	12%	5%	66%	16%	. .	1%
6	35%	29%	16%	18%	1%	2%
7	51%	21%	10%	15%	. .	2%
8	31%	50%	4%	12%	1%	1%
9	5%	18%	11%	3%	62%	1%
10	7%	38%	52%	1%	1%	. .
11	66%	22%	1%	10%	1%	. .
12	3%	2%	26%	68%	. .	. .
13	7%	34%	50%	8%	. .	1%
14	91%	3%	3%	2%	. .	. .
15	2%	33%	11%	53%	. .	1%
16	3%	44%	33%	19%	. .	1%
17	3%	3%	4%	76%	13%	1%
18	3%	90%	1%	6%	. .	. .

continued next page

*Expressed as a percentage of N. N = 676.

—— Correct response

TABLE 3.36--continued

Question Number	a	b	c	d	e	Omit
19	73%	3%	8%	12%	3%	1%
20	27%	1%	10%	3%	58%	1%
21	21%	11%	4%	2%	62%	1%
22	56%	2%	11%	5%	25%	1%
23	62%	6%	14%	7%	10%	1%
24	2%	76%	14%	7%	. .	1%
25	6%	11%	72%	9%	1%	1%
Part 2						
1	2%	6%	2%	85%	4%	1%
2	77%	9%	7%	2%	4%	1%
3	3%	9%	30%	2%	54%	1%
4	1%	19%	71%	3%	5%	1%
5	7%	51%	3%	14%	24%	1%
6	77%	3%	13%	3%	3%	1%
7	31%	14%	10%	12%	30%	2%
8	4%	5%	7%	57%	25%	1%
9	6%	4%	72%	11%	5%	1%
10	4%	27%	50%	8%	10%	1%
11	47%	14%	4%	15%	20%	1%
12	17%	40%	9%	18%	15%	1%
13	10%	11%	57%	12%	9%	1%
14	8%	4%	72%	10%	6%	1%
15	50%	17%	9%	19%	4%	1%
16	4%	15%	58%	20%	1%	1%
17	19%	20%	54%	6%	. .	1%
18	13%	13%	4%	62%	7%	1%
19	8%	14%	6%	10%	60%	3%
20	65%	14%	6%	9%	5%	1%
21	12%	7%	71%	9%	. .	1%
22	9%	14%	12%	62%	1%	1%

continued next page

TABLE 3.36--continued

Question Number	a	b	c	d	e	Omit
23	9%	5%	71%	9%	5%	1%
24	15%	2%	6%	65%	10%	1%
25	3%	12%	77%	4%	3%	1%
Part 3						
1	90%	3%	2%	2%	3%	1%
2	79%	5%	3%	4%	8%	1%
3	6%	82%	4%	4%	3%	1%
4	30%	8%	54%	6%	. .	2%
5	36%	14%	25%	24%	. .	1%
6	31%	6%	42%	16%	5%	1%
7	3%	8%	12%	48%	27%	1%
8	6%	48%	8%	13%	25%	1%
9	5%	9%	14%	26%	46%	1%
10	8%	10%	6%	23%	51%	1%
11	9%	71%	2%	9%	8%	1%
12	87%	3%	3%	4%	1%	1%
13	14%	27%	4%	51%	3%	1%
14	9%	3%	66%	17%	5%	1%
15	7%	9%	41%	41%	. .	2%

TABLE 3.37

Item Responses to the Questions on Test 48: Cans*

Question Number	a	b	c	d	e	Omit
Part 1						
1	1%	98%	. .	. .	. .	. .
2	29%	3%	64%	1%	3%	. .
3	3%	37%	1%	57%	2%	1%
4	2%	6%	64%	3%	24%	1%
5	1%	1%	94%	4%	. .	. .
6	27%	46%	11%	15%	1%	. .
7	69%	14%	6%	10%	1%	1%
8	20%	72%	3%	4%	1%	. .
9	3%	7%	4%	2%	85%	. .
10	2%	22%	76%	. .	1%	. .
11	71%	24%	1%	2%	2%	. .
12	1%	2%	7%	91%	. .	. .
13	3%	22%	73%	3%	. .	. .
14	98%	. .	2%	. .	. .	. .
15	. .	39%	5%	55%	1%	1%
16	1%	66%	20%	12%	1%	. .
17	2%	. .	. .	97%	1%	. .
18	1%	98%	. .	1%	. .	. .
19	89%	1%	4%	6%	. .	. .
20	12%	. .	3%	. .	86%	. .
21	4%	. .	. .	. .	96%	. .
22	84%	. .	2%	1%	13%	1%
23	96%	1%	1%	. .	2%	1%
24	1%	85%	10%	4%	. .	. . .
25	1%	8%	87%	4%	. .	. .

continued next page

*Expressed as a percentage of N. N = 182.

—— Correct response.

TABLE 3.37--continued

Question Number	a	b	c	d	e	Omit
Part 2						
1	. .	. .	. .	99%	1%	1%
2	88%	6%	4%	. .	1%	. .
3	2%	4%	10%	. .	83%	1%
4	. .	5%	93%	. .	1%	1%
5	1%	88%	1%	5%	5%	. .
6	96%	1%	1%	1%	2%	. .
7	36%	10%	2%	7%	45%	1%
8	2%	1%	1%	92%	4%	1%
9	1%	1%	97%	. .	2%	1%
10	1%	7%	82%	2%	8%	1%
11	66%	13%	1%	7%	14%	. .
12	9%	72%	3%	8%	8%	. .
13	1%	2%	91%	2%	4%	1%
14	. .	. .	96%	1%	3%	. .
15	74%	3%	1%	23%	. .	1%
16	. .	5%	67%	27%	1%	. .
17	7%	18%	74%	1%	1%	1%
18	5%	8%	. .	86%	1%	1%
19	2%	4%	1%	3%	89%	1%
20	94%	3%	. .	3%	1%	. .
21	3%	1%	95%	2%	. .	. .
22	2%	2%	8%	88%	. .	. .
23	4%	2%	89%	4%	1%	. .
24	12%	2%	2%	76%	8%	1%
25	1%	. .	98%	1%	1%	. .

continued next page

TABLE 5.37--*continued*

Question Number	a	b	c	d	e	Omit
Part 3						
1	*99%*	. .	1%	. .	1%	. .
2	*97%*	1%	. .	2%	1%	. .
3	2%	*95%*	1%	2%	1%	1%
4	15%	4%	*80%*	. .	. .	. .
5	42%	8%	13%	*37%*	. .	. .
6	*49%*	2%	41%	8%	. .	. .
7	. .	*8%*	13%	55%	24%	1%
8	1%	*66%*	3%	3%	26%	1%
9	1%	2%	4%	16%	*77%*	. .
10	1%	2%	. .	10%	*87%*	. .
11	2%	*93%*	. .	3%	2%	. .
12	*100%*	. .	. .	. .	. .	. .
13	2%	16%	. .	*82%*	. .	. .
14	8%	. .	*75%*	15%	2%	. .
15	2%	2%	27%	*68%*	1%	. .

TABLE 3.38

Item Responses to the Questions on Test 48: Cannots*

Question Number	a	b	c	d	e	Omit
Part 1						
1	21%	48%	10%	16%	5%	. .
2	37%	9%	30%	4%	20%	. .
3	13%	36%	13%	35%	4%	. .
4	7%	15%	36%	15%	25%	1%
5	21%	11%	40%	27%	1%	. .
6	35%	16%	23%	24%	1%	2%
7	38%	30%	13%	18%	1%	1%
8	33%	37%	7%	20%	1%	2%
9	4%	33%	16%	4%	41%	1%
10	12%	53%	29%	5%	2%	. .
11	56%	23%	3%	18%	1%	. .
12	7%	3%	50%	39%	. .	1%
13	14%	32%	32%	21%	. .	. .
14	80%	7%	5%	7%	. .	. .
15	7%	33%	11%	49%	. .	1%
16	4%	32%	38%	26%	. .	. .
17	4%	7%	9%	48%	31%	1%
18	7%	76%	2%	14%	1%	. .
19	52%	8%	13%	19%	7%	2%
20	31%	2%	23%	4%	39%	2%
21	32%	20%	12%	7%	29%	1%
22	34%	6%	20%	10%	29%	1%
23	29%	13%	30%	15%	14%	1%
24	3%	63%	21%	11%	1%	1%
25	7%	14%	54%	20%	3%	1%

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*Expressed as a percentage of N. N = 182.

—— Correct response.

TABLE 3.38--continued

Question Number	a	b	c	d	e	Omit
Part 2						
1	7%	12%	5%	64%	9%	2%
2	53%	18%	14%	5%	9%	1%
3	6%	13%	49%	5%	26%	1%
4	4%	26%	47%	9%	12%	2%
5	16%	20%	4%	23%	35%	1%
6	49%	9%	31%	3%	4%	3%
7	24%	16%	18%	16%	23%	2%
8	7%	12%	15%	23%	41%	3%
9	19%	8%	34%	26%	11%	2%
10	8%	34%	32%	15%	10%	1%
11	25%	13%	9%	25%	26%	2%
12	19%	19%	18%	19%	23%	3%
13	18%	18%	34%	19%	11%	2%
14	21%	12%	37%	20%	9%	1%
15	22%	30%	22%	13%	12%	2%
16	10%	27%	40%	19%	2%	3%
17	32%	19%	32%	13%	1%	3%
18	17%	23%	13%	37%	9%	2%
19	13%	25%	12%	14%	35%	2%
20	40%	19%	10%	18%	12%	1%
21	20%	16%	42%	18%	1%	3%
22	19%	28%	19%	29%	2%	2%
23	12%	9%	52%	17%	8%	3%
24	19%	5%	15%	48%	10%	2%
25	8%	29%	47%	9%	6%	2%

continued next page

TABLE 3.38--continued

Question Number	a	b	c	d	e	Omit
Part 3						
1	76%	8%	5%	6%	4%	1%
2	52%	11%	7%	9%	18%	3%
3	14%	60%	10%	7%	8%	1%
4	42%	12%	32%	10%	1%	3%
5	28%	21%	34%	16%	1%	1%
6	12%	11%	32%	27%	15%	2%
7	8%	7%	11%	41%	30%	3%
8	12%	29%	18%	19%	21%	1%
9	9%	16%	27%	27%	20%	2%
10	16%	19%	16%	26%	19%	3%
11	15%	42%	7%	19%	16%	2%
12	69%	4%	12%	10%	2%	3%
13	23%	32%	8%	26%	9%	2%
14	6%	8%	59%	14%	11%	2%
15	9%	17%	49%	22%	. .	3%

Space does not permit an analysis of the results of this final examination in the same pattern as for the tests previously discussed. The relative success of the Test Group, the Cans, and the Cannots for the four areas of study which were shown in Figure 3.10[1] is presented in Figure 3.12.

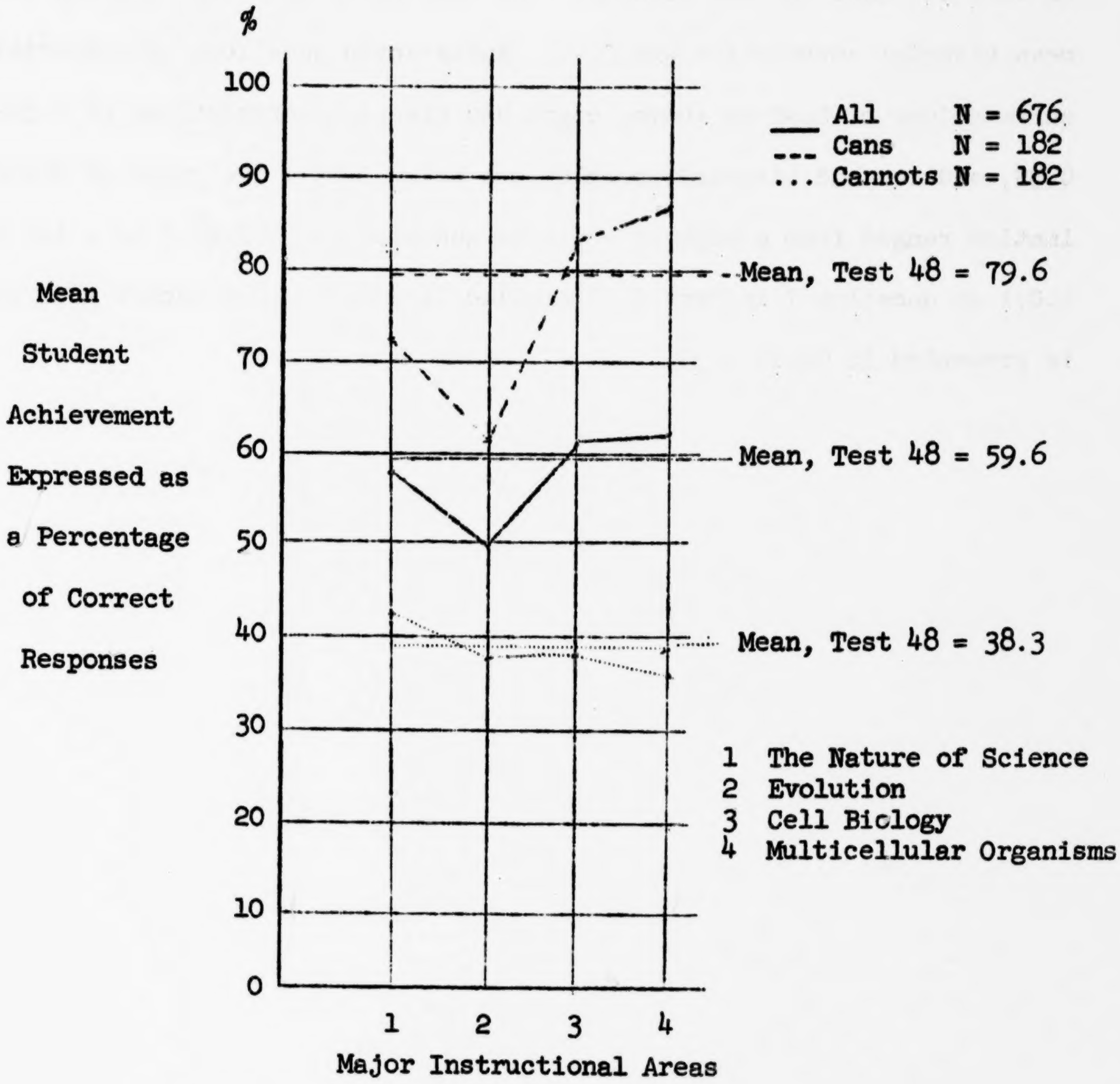

Fig. 3.12.--Percentage of Students in the Test Group, Cans, and Cannots Selecting the Best Response to Questions in the Four Areas of Test 48.

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[1] See p. 183.

It will be noted that for the questions designed to assess the nature of science the differences in mean achievement dropped 15 percent from the Cans to the Test Group, and another 15 percent from the Test Group to the Cannots.

Each of the questions in Test 48 was a positive discriminator between the Cans and the Cannots. The mean difficulty was 0.59 and the mean biserial correlation was 0.48. Forty-seven questions had biserial correlations of 0.40 or above, eight had biserial correlations of 0.30-0.39, and ten had biserial correlations below 0.29. The ratio of discrimination ranged from a high of 4.5:1 on question 10 in Part 3 to a low of 1.0:1 on question 7 in Part 3. Detailed data on the Can-Cannot analysis is presented in Table 3.39.

TABLE 3.39

Can-Cannot Analysis of Test 48

N = 676 Cans and Cannots each = 27% of N, or = 182

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		P_{BIS}	Difficulty
		N	%	Direction	Ratio		
Part 1							
1 . . .	Can	179	98%	+	2.0:1	0.69	0.78
	Cannot	88	48%				
2 . . .	Can	117	64%	+	2.1:1	.35	.51
	Cannot	55	30%				
3 . . .	Can	104	57%	+	1.6:1	.22	.50
	Cannot	63	35%				
4 . . .	Can	117	64%	+	1.8:1	.29	.47
	Cannot	66	36%				
5 . . .	Can	171	94%	+	2.4:1	.62	.66
	Cannot	72	40%				
6 . . .	Can	83	46%	+	2.8:1	.35	.29
	Cannot	29	16%				
7 . . .	Can	125	69%	+	1.7:1	.32	.51
	Cannot	70	38%				
8 . . .	Can	131	72%	+	1.9:1	.36	.50
	Cannot	67	37%				
9 . . .	Can	154	85%	+	2.0:1	.47	.62
	Cannot	75	41%				
10 . . .	Can	138	76%	+	2.6:1	.47	.52
	Cannot	53	29%				
11 . . .	Can	130	71%	+	1.2:1	.16	.66
	Cannot	102	56%				
12 . . .	Can	165	91%	+	2.3:1	.58	.68
	Cannot	71	39%				
13 . . .	Can	132	73%	+	2.2:1	.41	.50
	Cannot	59	32%				
14 . . .	Can	179	98%	+	1.2:1	.46	.91
	Cannot	146	80%				
15 . . .	Can	100	55%	+	1.1:1	.06	.53
	Cannot	89	49%				

continued next page

TABLE 3.39--continued

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		P_{BIS}	Difficulty
		N	%	Direction	Ratio		
16 . . .	Can	120	66%	+	2.0:1	0.35	0.44
	Cannot	58	32%				
17 . . .	Can	176	97%	+	2.0:1	.65	.76
	Cannot	87	48%				
18 . . .	Can	178	98%	+	1.2:1	.50	.90
	Cannot	139	76%				
19 . . .	Can	162	89%	+	1.7:1	.45	.73
	Cannot	94	52%				
20 . . .	Can	156	86%	+	2.1:1	.54	.58
	Cannot	71	39%				
21 . . .	Can	174	96%	+	3.3:1	.72	.62
	Cannot	52	29%				
22 . . .	Can	153	84%	+	2.5:1	.52	.56
	Cannot	61	34%				
23 . . .	Can	175	96%	+	3.3:1	.72	.62
	Cannot	52	29%				
24 . . .	Can	155	85%	+	1.3:1	.28	.76
	Cannot	114	63%				
25 . . .	Can	158	87%	+	1.5:1	.39	.72
	Cannot	99	54%				
Part 2							
1 . . .	Can	180	99%	+	1.5:1	.66	.85
	Cannot	117	64%				
2 . . .	Can	161	88%	+	1.6:1	.42	.77
	Cannot	96	53%				
3 . . .	Can	151	83%	+	3.1:1	.57	.54
	Cannot	48	26%				
4 . . .	Can	170	93%	+	1.9:1	.56	.71
	Cannot	86	47%				
5 . . .	Can	161	88%	+	4.4:1	.67	.51
	Cannot	36	20%				
6 . . .	Can	175	96%	+	1.9:1	.61	.77
	Cannot	89	49%				

continued next page

TABLE 3.39--continued

QUESTION NUMBER	Frequency on Correct Answer	N	%	Discrimination Direction	Discrimination Ratio	P_{BIS}	Difficulty
7 . . .	Can	81	45%	+	1.9:1	0.24	0.30
	Cannot	42	23%				
8 . . .	Can	167	92%	+	4.0:1	.69	.57
	Cannot	41	23%				
9 . . .	Can	176	97%	+	2.8:1	.72	.72
	Cannot	62	34%				
10 . . .	Can	149	82%	+	2.5:1	.51	.50
	Cannot	58	32%				
11 . . .	Can	120	66%	+	2.6:1	.42	.47
	Cannot	46	25%				
12 . . .	Can	131	72%	+	3.7:1	.53	.40
	Cannot	35	19%				
13 . . .	Can	165	91%	+	2.7:1	.61	.57
	Cannot	61	34%				
14 . . .	Can	175	96%	+	2.5:1	.68	.72
	Cannot	68	37%				
15 . . .	Can	134	74%	+	3.3:1	.52	.50
	Cannot	40	22%				
16 . . .	Can	49	27%	+	1.4:1	.11	.20
	Cannot	34	19%				
17 . . .	Can	135	74%	+	2.2:1	.42	.54
	Cannot	59	32%				
18 . . .	Can	156	86%	+	2.2:1	.52	.62
	Cannot	68	37%				
19 . . .	Can	162	89%	+	2.5:1	.57	.60
	Cannot	64	35%				
20 . . .	Can	171	94%	+	2.3:1	.62	.65
	Cannot	72	40%				
21 . . .	Can	172	95%	+	2.2:1	.63	.71
	Cannot	76	42%				
22 . . .	Can	161	88%	+	3.0:1	.60	.62
	Cannot	53	29%				
23 . . .	Can	162	89%	+	1.7:1	.45	.71
	Cannot	94	52%				

continued next page

TABLE 3.39--continued

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		p_{BIS}	Difficulty
		N	%	Direction	Ratio		
24 . . .	Can	138	76%	+	1.5:1	0.30	0.65
	Cannot	88	48%				
25 . . .	Can	179	98%	+	2.1:1	.69	.77
	Cannot	85	47%				
Part 3							
1 . . .	Can	180	99%	+	1.3:1	.57	.90
	Cannot	138	76%				
2 . . .	Can	176	97%	+	1.8:1	.63	.79
	Cannot	95	52%				
3 . . .	Can	172	95%	+	1.5:1	.46	.82
	Cannot	110	60%				
4 . . .	Can	146	80%	+	2.4:1	.49	.54
	Cannot	59	32%				
5 . . .	Can	67	37%	+	2.3:1	.27	.24
	Cannot	29	16%				
6 . . .	Can	89	49%	+	4.0:1	.44	.31
	Cannot	22	12%				
7 . . .	Can	14	8%	+?	1.0:1	.03	.08
	Cannot	13	7%				
8 . . .	Can	121	66%	+	2.2:1	.38	.48
	Cannot	53	29%				
9 . . .	Can	140	77%	+	3.8:1	.56	.46
	Cannot	36	20%				
10 . . .	Can	158	87%	+	4.5:1	.67	.51
	Cannot	35	19%				
11 . . .	Can	169	93%	+	2.2:1	.59	.71
	Cannot	76	42%				
12 . . .	Can	182	100%	+	1.4:1	.62	.87
	Cannot	126	69%				
13 . . .	Can	149	82%	+	3.1:1	.56	.51
	Cannot	48	26%				
14 . . .	Can	136	75%	+	1.2:1	.18	.66
	Cannot	107	59%				

continued next page

TABLE 3.39--continued

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		PBIS	Difficulty
		N	%	Direction	Ratio		
15 . . .	Can Cannot	124 40	68% 22%	+	3.1:1	0.47	0.41
AVERAGE . . .					2.2:1	0.48	0.59

Because the teaching of science as inquiry forms a major structural element in the themes and objectives of the BSCS materials,[1] those questions categorized as assessing student understandings of the nature of science will be the questions selected for discussion.

Nine questions were developed to assess selected aspects of the nature of theory within the part of the test on the nature of science. In questions 12, 13, 15, and 25 in Part 1, and 16 and 23 in Part 2, the subject matter was scientific theory without its being imbedded in other content. In questions 14, 16, and 19 of Part 1, the nature of theory was approached through the subject matter of evolution. Question 16 in Part 2 relates a specific idea in biology, DNA, to its potential fruitfulness in theory construction. Figure 3.13 shows the relative success of the Test Group, Cans, and Cannots on these questions.

Students were most successful in responding to question 14 in Part 1 which was designed to assess their understanding of observation. Question 15 in Part 1 discriminated the least among the groups.

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[1] Joseph J. Schwab, Biology Teachers' Handbook, (New York: John Wiley and Sons, Inc., 1963), pp. 30-42.

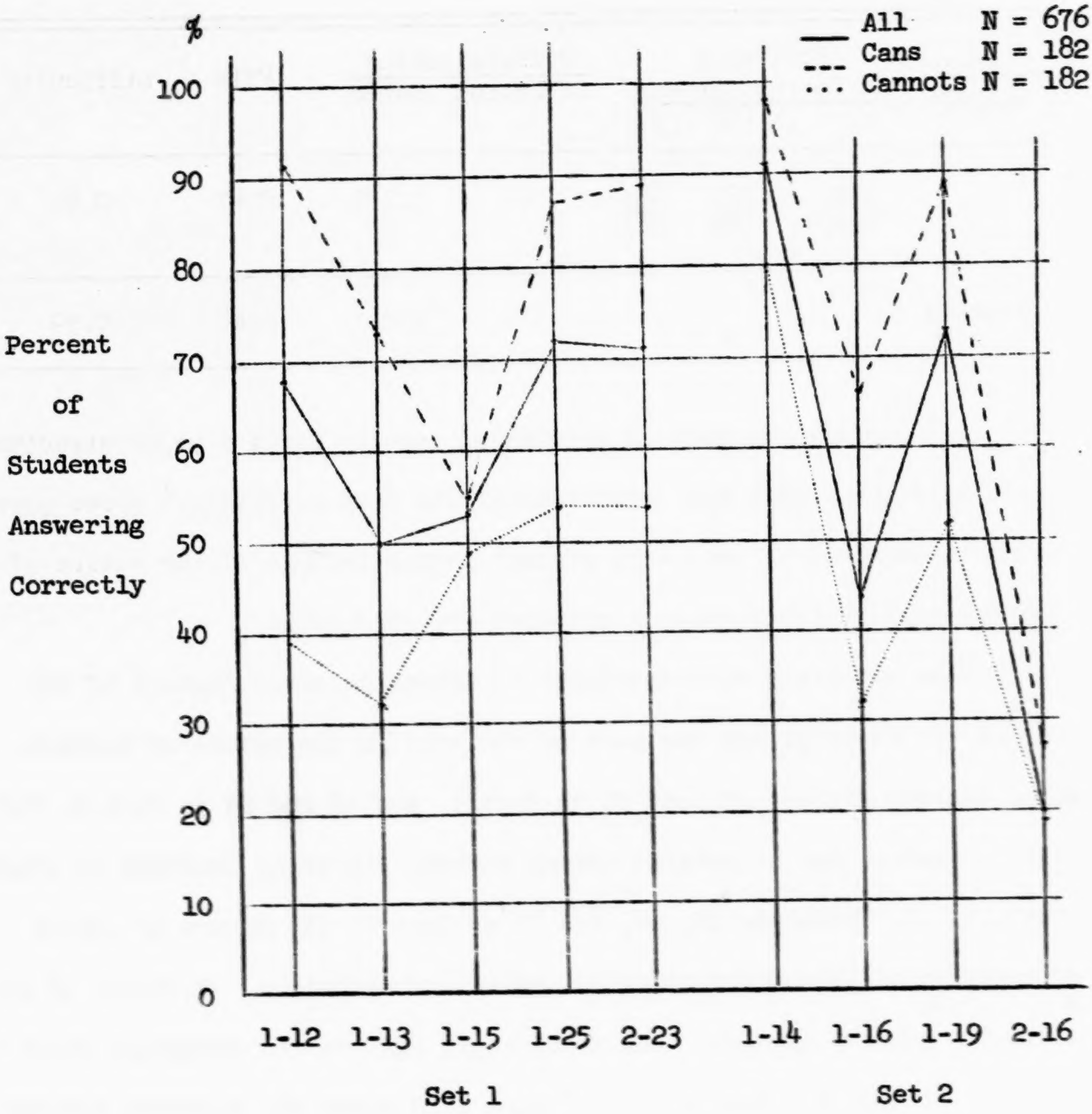

Fig. 3.13.--Questions grouped as assessing aspects of the nature of theory. In Set 1 the subject matter is the theory itself and in Set 2 the subject matter is from biological evolution and DNA.

Question 16 of Part 2 was the most difficult question in this series for each student group. In using this question for grading purposes the participating teachers considered both "c" and "d" as correct responses to the question. Four of the five choices in question 16 were correct statements, but the student was to respond to the best statement from the standpoint of its fruitfulness in developing theory in biology. From this standpoint the writer designed response "d" as a more discriminating response than "c," as it is a more general statement regarding the significance of DNA in biological theory.

On the basis of the responses to these nine questions on the nature of theory, it seems that by the end of the first semester observation was understood by the students in the contexts in which it was presented in the questions, but that the relationships and distinctions among theory, hypothesis, and assumption remained confused. The question which, in the writer's judgment, has the greatest educational significance is question 16 of Part 1. This question required students to label Darwin's idea of changing organisms as a theory, an observation, an assumption, or an hypothesis at the time of its formulation in 1843. It required that the student place a biological conception in its historical context in order to select the most appropriate response. As previously indicated, all students found this the most difficult question.

Seven questions were developed to assess selected aspects of interpreting experiments. The mean achievement of the Test Group, Cans, and Cannots on each of these questions is shown in Figure 3.14.

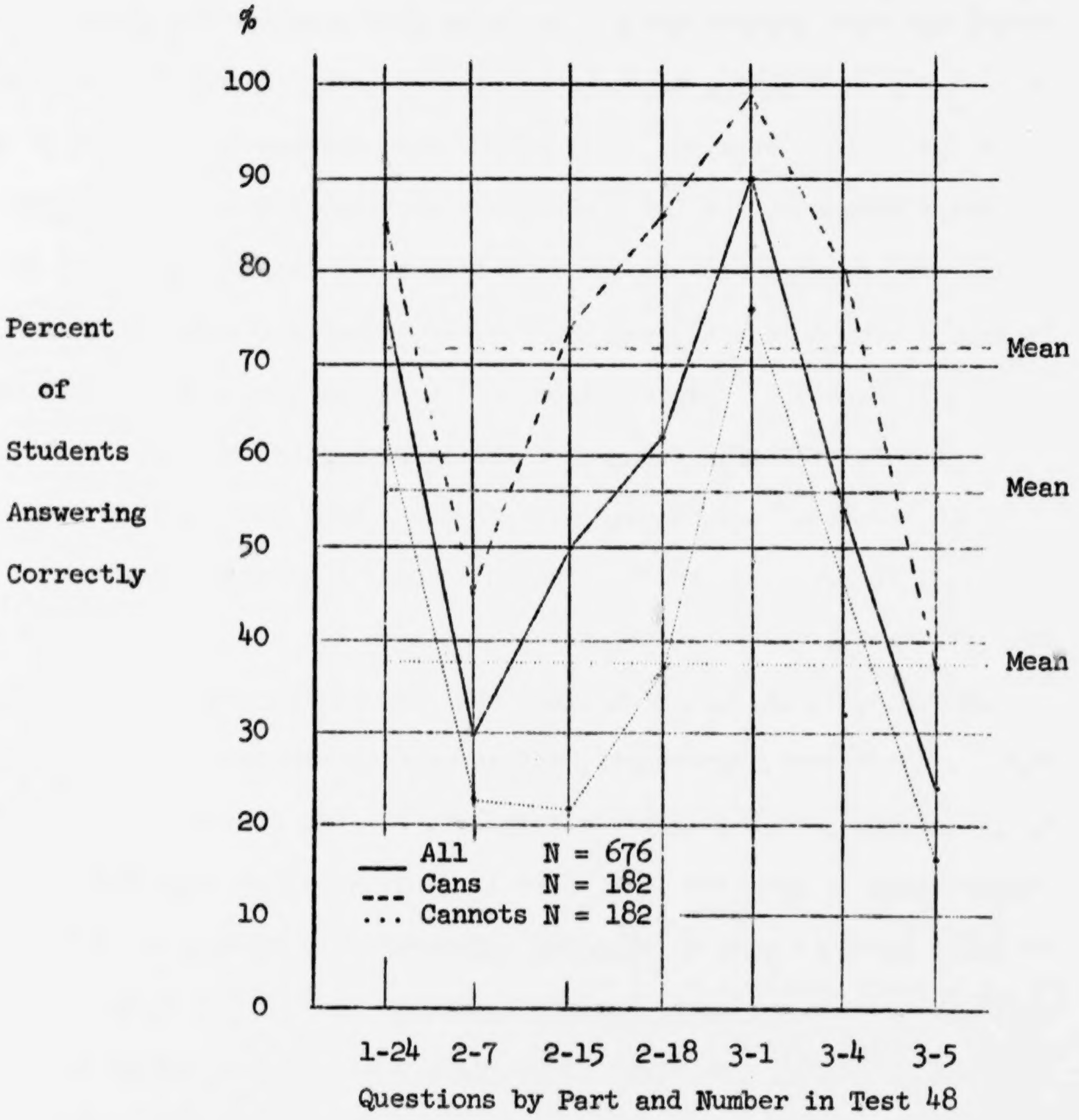

Fig.3.14.--Questions grouped as assessing aspects of interpreting experiments within the major test area on the nature of science.

The two easiest questions for the Test Group in this series were question 24 in Part 1 and question 1 of Part 3. The major distractor for each of the three groups on question 24 was that "facts are important to scientists because they are the main things scientists deal with."

This response was selected over the more appropriate response that "facts may be interpreted as giving support to or contradicting scientific theories." Those Cannots who failed to select the best response to question 1 of Part 3, 24 percent of the Cannots, scattered almost equally among the distractors.

Question 7 of Part 2 dealt with proof that several chemicals existed when life first developed. The purpose of this question was to assess the understanding that students had of the idea of proof within scientific inquiry as it was developed over the first semester through study of the heterotroph hypothesis. This question was one of the more difficult questions for all groups with "amino acids having been proved to exist when life first developed" as the major distractor. The best response was that "none of the chemicals have been proved to exist when life first developed." The text and laboratory emphasized the heterotroph hypothesis and its supporting evidence which strongly suggests that amino acids may have existed when life first developed. This body of argument and evidence seems to have been translated into proof by many students.

The idea of proof and of hypothesizing, as contrasted with concluding, were further assessed by question 15 of Part 2. This question was even more difficult for the Cannots than question 7 but was much easier for the Cans. The major distractor for the Test Group and the Cans was response "d," that the data provided in the description of an experiment would enable a scientist to "conclude that enzymes were crystals," rather than to "devise tests for an hypothesis that the crystals were enzymes." The Can group recognized the problem as dealing with enzymes which was not true for the Cannot group. However, on the basis of a single experiment 23 percent of the Cans selected the response that would conclude from a single experiment that the crystals were enzymes.

Question 18 of Part 2 described an experiment in embryology. As can be seen from Figure 3.14, this question discriminated by a ratio of 2.2:1 as between the Cans and the Cannots. The major distractors for the Test Group were two responses which were partially correct, but they were not as specific and as appropriate as the most accurate response. The responses of the Cannot group scattered among the distractors.

Questions 4 and 5 of Part 3 were included to assess the students' ability to interpret from graphed data. Graphical interpretation was a major emphasis in the laboratory investigations. The major distractor for the Test Group, the Cans, and the Cannots was the curve on the graph which would be the inverse of the correct answer. All of the scientific information needed to respond correctly to question 4 was provided in the background data presented for the question. Question 5 was more difficult than 4 for each of the groups, and also the degree of discrimination between the Cans and Cannots was not as great as on question 4. The ability to answer question 5 correctly included the knowledge that boiling would inactivate the enzyme urease in the described activity; if this knowledge were not known by the student, his best response would have been response "a," which was represented by a curve of increasing amount of ammonia. This was the most highly selected distractor for the Test Group and the Cans; the Cannots selected the inverse of this curve as the major distractor.

Twenty-five percent of the questions in Test 48 were designed to assess aspects of the students' understanding of the nature of science which the writer considers as being within the BSCS theme of the teaching of science as inquiry. It has been shown that the mean achievement of the Test Group on these questions was 58 percent. In reflecting on this level of achievement, the data presented, and the discussion of the questions devoted to the nature of theory and interpreting experiments, it is necessary to make explicit the relevant context of instruction. It seems reasonable to assume that these students had not, in their previous science instruction, had experience in a formalized way with the nature of scientific knowledge. The minutes of the meetings with the teacher participants[1] provide evidence that the preparation of the teachers to this point in their careers had not enabled them to understand clearly the distinctions which were developed in this series of questions. Questions of the importance of teaching these distinctions and of formalizing them in evaluation were raised at various times during the discussion sessions. The teachers also indicated that the text was not consistent in its use of terminology and was not clear in developing the nature of scientific proof and of distinguishing among hypotheses, theories, and assumptions. The inductive development of the meaning of terms is a new departure in high school biology texts. This inductive development introduces terms through contextual definitions and subsequent qualification, elaboration, and specification of the range of meanings of some scientific terms which provides further precision to the term or idea as originally introduced. This approach avoids the resort to a glossary with its one "definition" of a term. This practice is consistent with the role of definition in science[1] but no assistance is provided to the teacher or student for this change from usual textbook procedure. In addition, the use of the "is" of identity[2] may give the student and teacher linguistic cues that the first contextual definition is the definition.

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[1] These minutes are not published but are available to interested research workers on request to the writer.

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[1] See, for example, Henry Margenau, The Nature of Physical Reality. (New York: McGraw-Hill Book Co., 1950), pp. 220-244.

[2] Irving Lee, Language Habits in Human Affairs. (New York: Harpers, 1941), pp. 229-243. See discussion of "Science is" in pp. 1-10, Blue Version, Vol. 1.

Test 49, Genetics

Development of the Test

The Blue Version devotes three chapters to Mendelian genetics and two chapters to population genetics. The participating teachers in this project agreed that separate tests should be developed for these two areas of genetics as several teachers indicated that they might not be able to devote time to population genetics in this particular year.

Test 49 was developed to assess those aspects of genetics which were developed in chapters 14, 15, and 16 of the text and the accompanying laboratory exercises. Tests from the 1961-62 testing program had not been developed for the subject of genetics; therefore, the project director prepared analyses of the three chapters on Mendelian genetics and proposed four major areas of importance for the development of an evaluative instrument. These four areas were:

1. Historical development of the modern gene theory.
2. Probability.
3. Mendelian genetics.
4. Biochemical aspects of genetics.

This proposal was discussed by the participating teachers at a regular meeting and to these categories was added a fifth category on the interaction of heredity and environment. The project director developed a series of 50 questions, arranged by the five categories, for review by the participating teachers. Each question was discussed, reworded--when consensus indicated that rewording was necessary--and evaluated as to whether or not it should be used in the test.

Part of the discussion included consideration of the terms to include or exclude in the questions or as responses to questions. It was agreed that "homologous," "homozygous," and "heterozygous" should be excluded. The terms "allele," "genotype," "phenotype," "gene," "chromosome," and "sex-linked" could be included; but whenever possible, questions should be so worded that the terms would not be needed other than when understanding the term was the point of the question.

The teacher participants suggested that approximately 10 percent of the test be devoted to the interaction of heredity and environment, 20 percent to the historical development of the modern gene theory, 10 percent to probability, 30 percent to Mendelian genetics, and 30 percent to biochemical genetics. It was further suggested that the test consist of about 40 questions.

From the recorded group discussion the objectives of instruction for the area of study to be assessed by Test 49 may be stated as follows:

1. To understand the affect of the environment on the inherited characteristics of organisms.

2. To understand the contributions of Mendel, Sutton, Beadle, and Tatum to the growth and development of the modern gene theory.

3. To understand the nature of probability to the point of understanding the two basic principles of probability and being able to apply these to problems of inheritance.

4. To understand the mechanisms of the inheritance of characteristics controlled by single genes and to be able

to solve problems by applying the laws of Mendel to cases involving one or two gene traits, sex inheritance, sex-linked traits, and multiple alleles.

5. To understand the contribution which biochemical analysis has made to understanding the nature of inheritance, including the relationships of genes to enzymes; the relationships of the nucleus to the cytoplasm; and interrelationships among DNA, RNA, enzymes, and protein synthesis.

The Test

Test 49 consists of 40 questions, 25 questions in Part 1 and 15 questions in Part 3. The two parts were devised to conform to the answer card and the total 40 questions are to be considered as a single test. A grid of the test questions by number, content, and classification as developed in the Taxonomy is shown in Table 3.40 below.

Using the terminology developed in the Taxonomy, 25 percent of the questions are classified by the project director as assessing aspects of knowledge (1.00) and 75 percent as assessing understandings and skills at the levels of comprehension, application, analysis, and synthesis (2.00 and above). One question on Test 49 is classified at the 5.20 level in accordance with the Taxonomy. The completed test was slightly different from that proposed by the participants in that 10 percent was devoted to the interaction of heredity and environment, 17.5 percent to the historical development of the modern gene theory, 10 percent to probability, 32.5 percent to Mendelian genetics, and 30 percent to biochemical genetics. A copy of the test as given to the students in the Test Group follows.

TABLE 3.40

Test Analysis Grid for Test 49

(Using the Taxonomy on the horizontal axis)

Part 1
Part 2 —

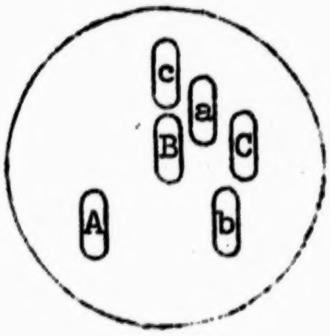
CONTENT	1.00 Knowledge		2.00 Comprehension 2.20	3.00 Application 3.00	4.00 Analysis 4.20	5.00 Synthesis 5.20
	1.10	1.20				
Interaction of Heredity and Environment					9 15 14 15	
Historical Development						
General		22				
Mendel	16				12 10	
Sutton	5	8				
Beadle & Tatum					19	
Probability				6 7 8 24		
Mendelian Genetics						
General	2					
Monohybrid				3 11 17 18	21 23	
Sex inheritance	7					
Sex linked traits				10	20	
Gametes				4		
Multiple Alleles					6 12	
Biochemical Genetics						
General	1	13			5	
One gene-One enzyme			2	13	3 9 4	
DNA-RNA-Protein						25
Mutation	1	11				
Interpreting Experiments					14	

TEST TITLE: Genetics Part 1 Test Number: 49

DIRECTIONS: Write the test number and title, your name, period, teacher, and date on your answer sheet. Mark the best answer by filling in the bubble exactly as shown in the sample. Use only the special pencil in marking your answer sheet. Erase completely any marks you change. DO NOT MARK ON THIS PAPER.

1. Mutations are basically the result of a change in

   a. the DNA code.
   b. ribosome RNA.
   c. proteins.
   d. the cell cytoplasm.
   e. transfer RNA.



2. In the drawing above, genes which are alleles would be on chromosomes:

   a. A and B.
   b. C and C.
   c. c and a.
   d. b and b.
   e. B and b.

3. If green is dominant to yellow and a pure yellow organism is crossed with a pure green organism, the F_1 organisms will be:

   a. all green.
   b. all yellow.
   c. 1 green to 1 yellow.
   d. 3 green to 1 yellow.
   e. all yellowish-green.

4. An organism with the genotype AABb could only produce sperm cells like:

    a. AABb.
    b. AB and Ab.
    c. AA and Bb.
    d. AA.
    e. Bb.

-2-*

5. Sutton's work indicated a direct relationship between Mendel's factors and the behavior of:

    a. genes.
    b. gametes.
    c. nuclei.
    d. chromosomes.
    e. DNA.

A special deck of cards is made up with equal numbers of only four kinds of cards: red, orange, green, and blue.

6. If the cards are well shuffled, what is the probability of drawing a blue card when 1 card is drawn?

    a. 1/1.
    b. 1/2.
    c. 1/3.
    d. 1/4.
    e. 1/16.

7. If the cards are well shuffled, what is the probability of drawing a red card and a green card when two cards are drawn?

    a. 1 out of 1.
    b. 1 out of 2.
    c. 1 out of 3.
    d. 1 out of 4.
    e. 1 out of 16.

8. If three cards are drawn from the deck one after the other, and each time the card was orange, what is the probability that the next card drawn will be orange? (A card is replaced after drawing and the deck is shuffled each time before drawing.)

    a. 1 in 2.
    b. 1 in 3.
    c. 1 in 4.
    d. 1 in 12.
    e. 1 in 16.

9. A basic assumption of the geneticists approach to the study of heredity is that

   a. factors which a person develops during his life become a part of his inheritance.
   b. if an organism uses some of its structures these structures will change and the change will be inherited.
   c. the characteristics an organism has is due to the genes it has inherited.
   d. the genes which control inheritance are passed on from generation to generation without change.
   e. the environment affects the degree to which a particular inherited factor is expressed.

10. A type of color blindness is due to a sex-linked gene (c). Normal vision is dominant (C). A color-blind man marries a homozygous normal woman. What is the probability that their female children will be carriers of color blindness?

   a. All. (1 in 1.)
   b. 1 in 4.
   c. 1 in 3.
   d. 1 in 2.
   e. None. (0 in 1.)

11. In a breeding experiment in which 50% of the offspring were "bb," the parents were:

   a. BB and bb.
   b. Bb and Bb.
   c. Bb and bb.
   d. bb and bb.
   e. BB and BB.

12. We now know that Mendel was fortunate in selecting the garden pea and the seven contrasting factors he studied because:

   a. all of the factors were on the same chromosome.
   b. all of the factors were on the same pair of homologous chromosomes.
   c. most of the factors were on different chromosomes.
   d. most of the factors were on different pairs of homologous chromosomes.
   e. all of the factors were on different pairs of homologous chromosomes.

13. In a species of moth a series of step by step reactions has been established as shown below.

tryptophane
↓
substance A
↓
substance B
↓
brown pigment
↓

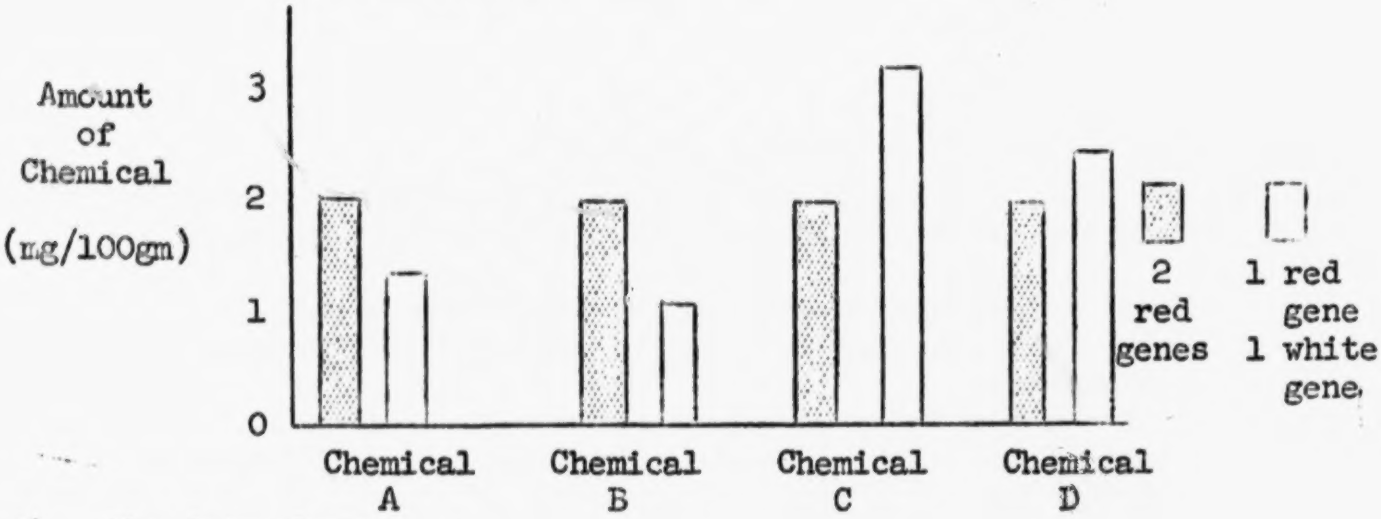
According to the hypothesis proposed by Beadle and Tatum there would be __?_____ gene(s) necessary for the production of the brown pigment from tryptophane.

a. 1.
b. 2.
c. 3.
d. 4.
e. 7.

-4-*

Hypothesis: A recessive gene is inactive in the presence of a dominant gene.

Experiment: A biochemical analysis of red eyed fruit flies was made. One group of flies had two genes for red eyes and one group had one gene for red eyes and one gene for white eyes. The amount of four chemicals present in each group is shown below.



14. The data above:

a. support the hypothesis.
b. prove that the hypothesis is true.
c. do not support the hypothesis.
d. prove that the hypothesis is false.
e. are not a test of the hypothesis.

15. DDT had been found to kill most house flies. After several years of spraying however, the number of flies which were alive after spraying began to increase. Laboratory tests indicated that these flies were not affected by DDT. The best explanation for these events would be that:

    a. DDT resistance in the flies developed because of the spraying with DDT.
    b. DDT resistance may be a rare but normal variation in house flies.
    c. DDT affected the flies in such a way that they made chemicals which destroyed it.
    d. DDT acts on flies in such a way that their inherited factors changed.

-5-*

16. One of Mendel's contributions to our understanding of heredity was that

    a. some factors were linked on the same chromosomes.
    b. heredity seemed to be controlled by a number of independent factors.
    c. the genes governing sex inheritance were carried on special chromosomes.
    d. chromosomes within the cell were the carriers of inherited factors.
    e. the heredity information was carried by the DNA code.

17. Whiteforelock (W) is dominant to normal forelock (w). A whiteforelock man and a normal forelock woman have three normal forelock children and one whiteforelock child. The genotype of the man is:

    a. WW.
    b. ww
    c. Ww.
    d. W.
    e. w.

18. In order to find out if a particular organism is Zz or ZZ for a particular trait it should be crossed with an organism which is

    a. Zz.
    b. zz.
    c. ZZ.
    d. closely related but does not show that trait.

19. Sir Archibald E. Garrod studied inherited diseases in man. By 1908 he had gathered evidence which lead him to the hypothesis that a certain inherited disease was the result of a person being unable to break down a specific chemical. He hypothesized that this was due to the absence or inactivity of an enzyme. This was dependent on the normal form of a specific gene.

    The work reported above is most important to the findings of:

    a. T. H. Morgan.
    b. Bridges.
    c. Sutton.
    d. Beadle and Tatum.
    e. Mendel.

20. A rare type of blindness is due to a dominant gene. What is the probability that two parents with normal vision will have children with this rare type of blindness.

    a. 1:1.
    b. 1:2.
    c. 1:3.
    d. 1:4.
    e. no chance.

21. A package of seeds when planted resulted in many normal seedlings and some albino seedlings. The way to produce the most albino corn is to cross:

    a. normal plants known to carry a gene for the albino factor.
    b. pure normal plant with plants known to carry a gene for the albino factor.
    c. pure normal plants with pure albino plants.
    d. albino plants with albino plants.

1. one gene, one enzyme.
2. The factors of inheritance are carried by the chromosomes.
3. DNA contains a four letter code for carrying genetic information.
4. Heredity seems to be controlled by a number of independent factors.
5. Traits may be linked.

22. The proper historical order of the events above, beginning with the earliest discovery to the most recent discovery is:

    a. 4, 5, 1, 2, 3.
    b. 2, 4, 1, 5, 3.
    c. 4, 2, 5, 1, 3.
    d. 2, 5, 4, 3, 1.
    e. 5, 4, 2, 1, 3.

23. A rare type of mental illness is known to be due to a recessive gene. A woman whose mother had this illness is married to a man whose father also had the illness. What is the chance that the children of this man and woman--they are both normal--will have this mental illness?

    a. 1 to 1.
    b. 1 to 3.
    c. 1 to 2.
    d. 1 to 4.
    e. no chance.

24. If one kind of event has a chance happening (probability) of 1 in 4 and a second kind of event has a chance happening (probability) of 1 in 5 the chance (probability) that these two events will happen together is:

    a. 1 in 4.
    b. 1 in 5.
    c. 1 in 9.
    d. 1 in 20.
    e. 1 in 25.

1. transfer RNA.
2. enzymes.
3. amino acids.
4. DNA.
5. ribosome RNA.

25. A person is able to carry out a certain chemical action: substance A---------- substance B. Arrange the substances above in the order in which the "information" for the reaction is transferred from the origin of the "information" to the substance which carries out the reaction.

    a. 3, 4, 5, 1, 2.
    b. 4, 2, 5, 1, 3.
    c. 2, 3, 4, 1, 5.
    d. 2, 1, 4, 5, 3.
    e. 4, 1, 5, 3, 2.

TEST TITLE: Genetics Part 3 Test Number: 49

DIRECTIONS: Write the test number and title, your name, period, teacher, and date on your answer sheet. Mark the best answer by filling in the bubble exactly as shown in the sample. Use only the special pencil in marking your answer sheet. Erase completely any marks you change. DO NOT MARK ON THIS PAPER.

1. The hemoglobin of sickle-cell anemia differs from normal hemoglobin in:

    a. only the shape of the molecule.
    b. the number and kinds of amino acids.
    c. the number, but not the kinds of amino acids.
    d. only one amino acid.
    e. the kinds, but not the number of amino acids.

The model below represents a series of chemical reactions in living things. Refer to this model to answer questions 2 to 4.

$$\begin{tikzcd}
 & 1 \arrow[d] & & 2 \arrow[d] & & 3 \arrow[d] & \\
 & 4 \arrow[d] & & 5 \arrow[d] & & 6 \arrow[d] & \\
\text{Ornithine} \arrow[r, dashed, no head] & {} \arrow[r, dashed] & \text{substance X} \arrow[r, dashed, no head] & {} \arrow[r, dashed] & \text{substance Y} \arrow[r, dashed, no head] & {} \arrow[r, dashed] & \text{substance Z}
\end{tikzcd}$$

2. The chemicals numbered 1, 2, and 3 represent control chemicals known as

   a. amino acids.
   b. vitamins.
   c. proteins.
   d. enzymes.
   e. genes.

3. If substance 2 were changed chemically the amount of substance

   a. X would decrease.
   b. X would increase.
   c. X would not change.
   d. 3 would increase.
   e. 3 would decrease.

4. The change from substance X to substance Y can be done by substance

   a. 4 only.
   b. 5 only.
   c. 6 only.
   d. 4, 5, or 6.

5. Penicillium does not require biotin in its culture medium as Neurospora does. This suggests that:

   a. Neurospora can synthesize biotin but Penicillium cannot.
   b. Penicillium can synthesize biotin but Neurospora cannot.
   c. Neurospora and Penicillium can both live without biotin.
   d. Both Neurospora and Penicillium can synthesize biotin.
   e. Neither Neurospora nor Penicillium can synthesize biotin.

6. If a child has type O blood and the mother has type O blood the genotype of the father could be: (X=antigen A, Y=antigen B, and Z=no antigen)

   a. only XZ.
   b. XZ, YZ, or XX.
   c. only ZZ.
   d. XZ, YZ, or ZZ.
   e. XZ, XY, or YZ.

7. In the fruit fly, a fly with six body chromosomes and an X and a Y chromosome would be

   a. a male.
   b. a female.
   c. an exceptional male.
   d. an exceptional female.
   e. sterile.

8. The work of Sutton and Morgan provided evidence for the development of a chromosome theory of heredity. Historically, the next supporting evidence was the discovery of

   a. nondisjunction.
   b. the four letter code of DNA.
   c. the relation between genes and enzymes.
   d. the 1:2:1 ratio of a heterozygous by heterozygous cross.
   e. sex inheritance.

9. In living things genes act

   a. by moving from the nucleus to the cytoplasm where they form enzymes.
   b. by directly controlling the ADP-ATP cycle.
   c. only in the cells of the embryo before differentiation.
   d. by changing their code as cell differentiation progresses.
   e. by the enzymes they control.

10. The work of Mendel was:

    a. published and immediately recognized as important by scientists.
    b. published 40 years after Darwin's Origin of Species but would have provided support to his theory if it had been available at the same time.
    c. published shortly after Darwin's Origin of Species but was not recognized as important by scientists at the time.
    d. not published in a science journal and so was "lost" for many years.

11. The first effect of a gene mutation on cell activity is to change the kinds of

    a. enzymes produced.
    b. ribosome RNA produced.
    c. amino acids produced.
    d. proteins produced.
    e. vitamins produced.

12. A woman with type A blood married a man with type B blood. Their children could have blood type(s):

    a. A or B only.
    b. A or AB only.
    c. B or AB only.
    d. A, B, or AB only.
    e. A, B, AB or O only.

13. Neurospora is a unique organism for genetics experiments because it:

    a. has a small number of chromosomes.
    b. has many specialized body parts in which it is easy to see changes in inheritance.
    c. has a minimum of only one gene instead of paired genes for each inherited characteristic.
    d. is not normally able to synthesize any vitamins.

14. Experimental evidence indicates that the

    a. genes act alone in determining the phenotype of the adult organism.
    b. the cytoplasm is responsible for as many genetic factors as the genes in determining the phenotype of the adult organism.
    c. the genes and the cytoplasm act together in determining the phenotype of the adult organism.
    d. the genes, the cytoplasm, and the environment act together in determining the phenotype of the adult organism.
    e. the environment is more important than the genes in determining the phenotype of the adult organism.

15. 400 corn seedlings were grown in a light proof container. All the seedlings were white in color. After seven days the seedlings were placed in the light. A few days later 321 seedlings had turned green and 79 remained white. Scientists have interpreted these data to indicate that:

    a. green color is not an inherited factor in corn seedlings.
    b. the presence or absence of light cannot influence the action of genes in corn seedlings.
    c. the action of color genes in the corn seedling depends on the environment.
    d. for the 321 seedlings the white color was an acquired characteristic and proves that environment is more important than heredity.

Analysis of Test Results

Table 3.41 shows the frequency of total correct responses for the 652 students taking Test 49. The mean achievement for these students was 21.0 raw score points, or 53 percent, and the standard deviation was 6.5 raw score points.

TABLE 3.41

Distribution of Correct Scores for Test 49

NUMBER OF CORRECT CHOICES*	BOYS		GIRLS		TOTAL	
	Frequency	Per-centage	Frequency	Per-centage	Frequency	Per-centage
36-37 . . .	4	1.2	2	0.6	6	0.9
34-35 . . .	6	1.8	3	0.9	9	1.4
32-33 . . .	10	3.0	14	4.4	24	3.7
30-31 . . .	14	4.2	17	5.3	31	4.7
28-29 . . .	21	6.3	25	7.8	46	7.0
26-27 . . .	29	8.7	29	9.1	58	8.8
24-25 . . .	32	9.6	31	9.7	63	9.7
22-23 . . .	24	7.2	40	12.5	64	9.8
20-21 . . .	38	11.4	35	10.9	73	11.2
18-19 . . .	38	11.4	39	12.2	77	11.8
16-17 . . .	41	12.4	23	7.2	64	9.8
14-15 . . .	28	8.4	33	10.3	61	9.4
12-13 . . .	21	6.3	17	5.3	38	5.9
10-11 . . .	14	4.2	16	5.0	30	4.6
8- 9 . . .	11	3.3	6	1.9	17	2.6
6- 7 . . .	1	0.3	0		1	0.0
TOTALS	332	99.7	320	103.1	652	101.3

*40 is the maximum number possible.

When interpreting the differential responses of the students on Test 49, the ability of these students as determined by the DAT (VR + NA) is an important variable. Percentile scores for the DAT (VR + NA) of the Test Group, Cans, and Cannots, based upon the test publisher's percentile conversion tables, are shown in Figure 3.15.

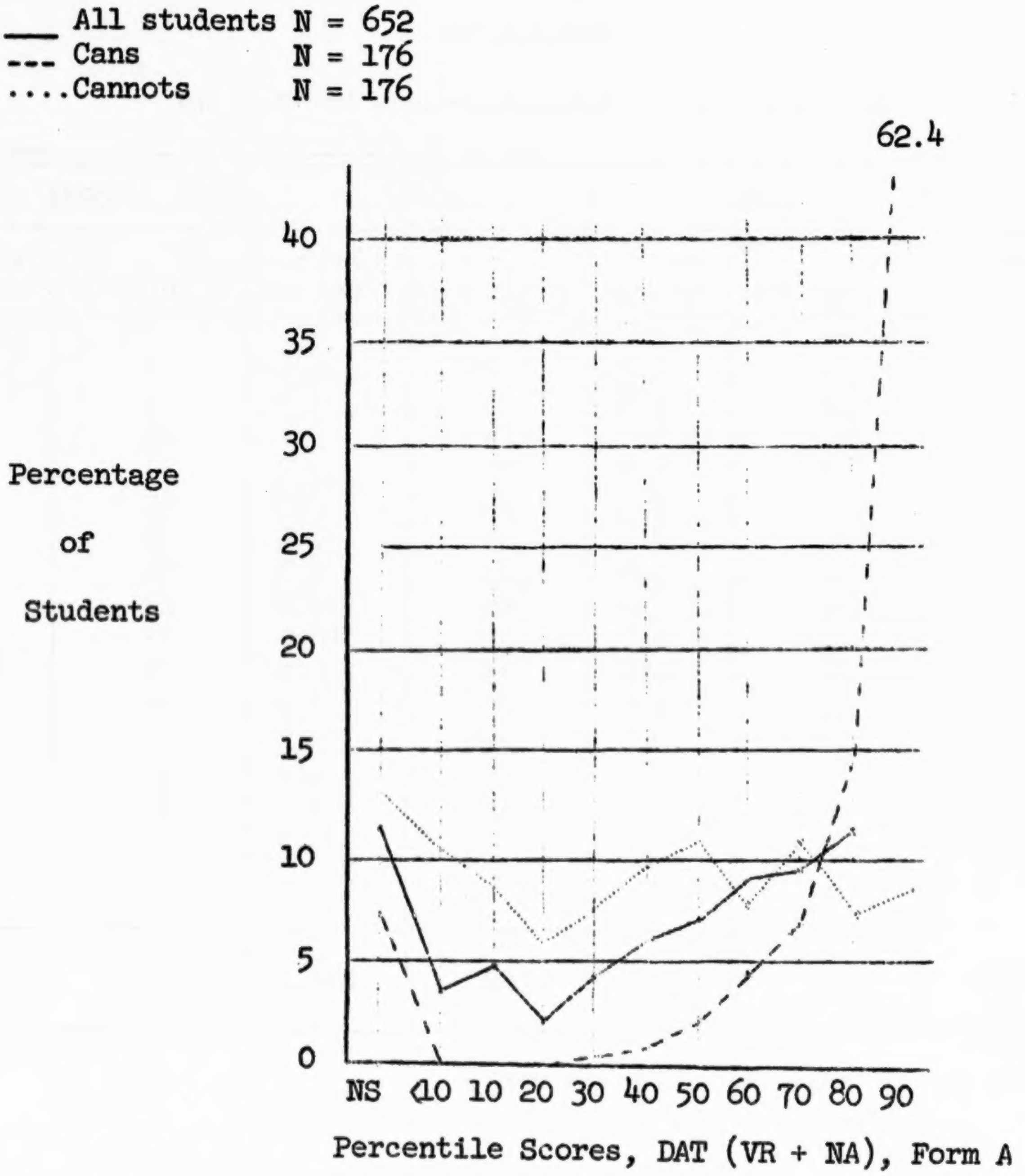


Fig. 3.15.--Frequency distributions for students taking Test 49 by publisher's percentile scores on the DAT (VR + NA).

The median score for the Cans falls above the 90th percentile, for the Test Group at about the 60th percentile, and for the Cannots at about the 45th percentile.

A detailed response pattern of the students taking Test 49 is shown in the item analysis presented in Table 3.42. The item responses for the Cans and Cannots are presented in Tables 3.43 and 3.44 respectively. Data for the discussion which follows were obtained from these tables.

TABLE 3.42

Item Responses to the Questions on Test 49: Test Group*

Question Number	a	b	c	d	e	Omit
Part 1						
1	81%	6%	3%	4%	6%	. .
2	12%	7%	12%	4%	62%	2%
3	68%	3%	6%	16%	7%	. .
4	12%	68%	18%	1%	. .	. .
5	36%	6%	4%	49%	4%	1%
6	2%	2%	2%	87%	7%	. .
7	1%	17%	2%	18%	62%	. .
8	4%	2%	75%	8%	10%	. .
9	3%	2%	46%	10%	38%	1%
10	32%	13%	4%	24%	26%	1%
11	8%	23%	67%	3%	. .	. .
12	19%	24%	17%	13%	26%	2%
13	9%	24%	45%	18%	4%	1%
14	13%	4%	27%	10%	44%	1%
15	28%	33%	9%	30%	1%	. .
16	6%	51%	11%	28%	3%	1%
17	5%	4%	86%	4%	. .	2%
18	15%	64%	14%	7%	. .	. .
19	13%	13%	12%	54%	7%	1%
20	2%	3%	1%	11%	82%	1%
21	14%	5%	6%	73%	1%	1%

continued next page

*Expressed as a percentage of N. N = 652

—— Correct response.

TABLE 3.42--continued

Question Number	a	b	c	d	e	Omit
22	17%	11%	46%	9%	16%	1%
23	4%	8%	20%	62%	6%	1%
24	1%	1%	13%	82%	2%	. .
25	13%	18%	14%	4%	49%	2%
Part 3						
1	13%	14%	9%	52%	12%	. .
2	19%	4%	8%	30%	38%	1%
3	25%	19%	36%	9%	10%	1%
4	8%	63%	10%	17%	1%	1%
5	24%	67%	3%	4%	1%	. .
6	7%	9%	25%	42%	12%	5%
7	67%	7%	12%	4%	8%	1%
8	22%	15%	23%	8%	27%	4%
9	14%	7%	10%	9%	60%	1%
10	4%	13%	31%	51%	1%	1%
11	43%	34%	14%	7%	. .	2%
12	4%	4%	4%	33%	53%	2%
13	32%	29%	24%	9%	. .	6%
14	16%	5%	20%	54%	4%	1%
15	7%	13%	66%	12%	1%	1%

TABLE 3.43

Item Responses to the Questions on Test 49: Cans*

Question Number	a	b	c	d	e	Omit
Part 1						
1	94%	2%	1%	. .	2%	1%
2	6%	1%	2%	2%	89%	2%
3	89%	2%	3%	4%	2%	. .
4	2%	87%	11%	. .	. .	. .
5	16%	2%	. .	80%	2%	. .
6	. .	1%	1%	99%	. .	. .
7	. .	4%	1%	6%	89%	1%
8	2%	. .	94%	1%	2%	. .
9	1%	. .	32%	16%	51%	. .
10	56%	5%	1%	18%	20%	1%
11	1%	7%	93%	. .	. .	. .
12	10%	14%	19%	13%	43%	2%
13	5%	11%	76%	8%	1%	. .
14	7%	1%	31%	4%	57%	1%
15	14%	64%	3%	19%	1%	. .
16	2%	89%	. .	9%	. .	1%
17	. .	1%	95%	3%	1%	. .
18	7%	88%	6%	. .	. .	. .
19	5%	7%	1%	88%	. .	. .
20	. .	2%	1%	5%	93%	. .
21	19%	1%	1%	79%	1%	. .

continued next page

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*Expressed as a percentage of N. N = 176.

___ Correct response.

TABLE 3.43--continued

Question Number	a	b	c	d	e	Omit
22	10%	5%	73%	2%	11%	1%
23	2%	6%	8%	81%	3%	. .
24	. .	. .	1%	99%	. .	. .
25	4%	15%	2%	2%	77%	1%
Part 3						
1	4%	3%	2%	81%	10%	1%
2	7%	2%	. .	19%	72%	. .
3	22%	16%	52%	3%	6%	. .
4	1%	88%	6%	5%	1%	. .
5	14%	84%	. .	2%	1%	. .
6	4%	2%	16%	70%	5%	2%
7	84%	. .	13%	2%	1%	. .
8	42%	5%	14%	1%	35%	2%
9	3%	1%	1%	1%	94%	1%
10	1%	7%	32%	60%	. .	. .
11	48%	45%	2%	4%	. .	1%
12	1%	2%	1%	15%	81%	1%
13	34%	25%	32%	6%	. .	3%
14	7%	1%	9%	82%	2%	1%
15	3%	7%	84%	4%	. .	2%

TABLE 3.44

Item Responses to the Questions on Test 49: Cannots*

Question Number	a	b	c	d	e	Omit
Part 1						
1	71%	12%	5%	10%	3%	. .
2	19%	14%	25%	6%	35%	1%
3	38%	4%	9%	35%	14%	1%
4	24%	51%	20%	2%	2%	1%
5	49%	13%	9%	25%	3%	1%
6	4%	5%	5%	70%	16%	1%
7	2%	31%	4%	25%	39%	. .
8	5%	5%	48%	22%	20%	1%
9	9%	6%	52%	8%	24%	1%
10	11%	28%	10%	24%	26%	1%
11	16%	40%	34%	9%	. .	. .
12	24%	28%	21%	15%	11%	1%
13	6%	38%	25%	23%	7%	1%
14	23%	10%	23%	16%	26%	2%
15	35%	13%	13%	39%	1%	1%
16	10%	21%	23%	39%	6%	1%
17	11%	7%	75%	6%	1%	1%
18	19%	44%	18%	18%	1%	1%
19	17%	13%	24%	25%	19%	2%
20	5%	6%	3%	20%	63%	2%
21	14%	13%	9%	61%	1%	3%

continued next page

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*Expressed as a percentage of N. N = 176.

—— Correct response.

TABLE 3.44--continued

Question Number	a	b	c	d	e	Omit
22	20%	24%	20%	14%	19%	2%
23	8%	7%	31%	43%	8%	2%
24	3%	3%	31%	59%	3%	1%
25	23%	20%	26%	7%	19%	4%
Part 3						
1	24%	26%	16%	22%	12%	1%
2	30%	7%	14%	35%	13%	2%
3	25%	23%	22%	14%	14%	2%
4	16%	38%	11%	31%	1%	2%
5	35%	44%	10%	6%	3%	2%
6	9%	16%	31%	18%	19%	6%
7	40%	19%	14%	7%	18%	2%
8	7%	22%	24%	19%	22%	6%
9	25%	16%	17%	15%	26%	2%
10	6%	24%	31%	35%	1%	3%
11	35%	28%	22%	8%	1%	5%
12	7%	6%	8%	51%	25%	3%
13	28%	30%	22%	11%	. .	9%
14	21%	13%	29%	28%	8%	1%
15	14%	16%	40%	27%	2%	1%

The five emphasis areas developed in planning Test 49 may be used for purposes of analyzing student achievement. A summary of the achievement of the Test Group, the Cans and the Cannots is presented in Table 3.45. Those questions which have been categorized as assessing aspects of the historical development of the modern gene theory were most difficult for all three groups. It is also of interest that each of these questions, with the exception of question 10 of Part 3, was a strong discriminator between the Can and Cannot groups. The students in all three groups were able to deal most adequately with those questions designed to measure aspects of probability and problems of Mendelian genetics. In evaluating the difficulty of these questions, it is necessary to consider the emphasis of instruction as well as the wording of particular questions. It will be noted that to this point in the tests which have been discussed very few questions have been developed to assess aspects of the historical development of biological conceptions. The difficulty which students had with these questions may well reflect the deemphasis on history in instruction rather than the inherent difficulty in the questions themselves.

The mean biserial correlation for the 40 questions of Test 49 was 0.46. All questions except question 3 of Part 3 were positive discriminators. Question 3 could have been clarified by adding a time dimension to the lead statement. Lack of a time dimension may have caused many students to give a short term response rather than a response which would have referred to events over a longer period of time. The test writer considered the response with a longer time duration as the best. Thirty-one of the 40 questions had biserial correlations

TABLE 3.45

Achievement of the Test Group, Cans, and Cannots for Five Areas of Emphasis in Test 49

EMPHASIS AREAS	Percent of Test	QUESTION NUMBER	MEAN ACHIEVEMENT Expressed as a Percentage of the Students Answering the Question Group Correctly		
			Test Group (N=652)	Cans (N=176)	Cannots (N=176)
Interaction of Heredity and Environment	10%	Part 1: Q.9, 15 Part 3: Q.14, 15	48%	70%	26%
Historical Development of the Modern Gene Theory	17.5%	Part 1: Q.5, 12, 16, 19, 22 Part 3: Q.8, 10	40%	64%	20%
Probability	10%	Part 1: Q.6, 7, 8, 24	77%	95%	54%
Mendelian Genetics	32.5%	Part 1: Q.2, 3, 4, 10, 11, 17, 18, 20, 21, 23 Part 3: Q.6, 7, 13	59%	79%	38%
Biochemical Genetics	30%	Part 1: Q.1, 13, 14, 25 Part 3: Q.1, 2, 3, 4, 5, 9, 11, 13	47%	67%	29%
Mean Achievement			53%	73%	33%

above 4.0. Two questions had biserial correlations between 0.30 and 0.39, and seven questions had biserial correlations below 0.30. The ratio of discrimination between Cans and Cannots ranged from 5.6 to 0.7. Detailed data on the Can-Cannot analysis is presented in Table 3.46.

TABLE 3.46

Can-Cannot Analysis of Test 49

N = 652 Cans and Cannots each = 27% of N, or = 176

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		p_{BIS}	Difficulty
		N	%	Direction	Ratio		
Part 1							
1 . . .	Can	166	94%	+	1.3:1	0.39	0.81
	Cannot	125	71%				
2 . . .	Can	156	89%	+	2.5:1	.57	.62
	Cannot	62	35%				
3 . . .	Can	157	89%	+	2.3:1	.55	.68
	Cannot	67	38%				
4 . . .	Can	153	87%	+	1.7:1	.42	.68
	Cannot	90	51%				
5 . . .	Can	140	80%	+	3.1:1	.55	.49
	Cannot	44	25%				
6 . . .	Can	174	99%	+	1.4:1	.62	.87
	Cannot	123	70%				
7 . . .	Can	157	89%	+	2.3:1	.55	.62
	Cannot	68	39%				
8 . . .	Can	166	94%	+	1.9:1	.57	.75
	Cannot	84	48%				
9 . . .	Can	90	51%	+	2.0:1	.29	.38
	Cannot	43	24%				
10 . . .	Can	99	56%	+	4.9:1	.51	.32
	Cannot	20	11%				
11 . . .	Can	163	93%	+	2.7:1	.64	.67
	Cannot	60	34%				
12 . . .	Can	75	43%	+	3.9:1	.40	.26
	Cannot	19	11%				
13 . . .	Can	133	76%	+	3.0:1	.51	.45
	Cannot	44	25%				
14 . . .	Can	54	31%	+	1.3:1	.10	.27
	Cannot	40	23%				
15 . . .	Can	112	64%	+	5.0:1	.54	.33
	Cannot	22	13%				

continued next page

TABLE 3.46--continued

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		P_{BIS}	Difficulty
		N	%	Direction	Ratio		
16 . . .	Can	156	89%	+	4.2:1	0.67	0.51
	Cannot	37	21%				
17 . . .	Can	168	95%	+	1.2:1	.38	.86
	Cannot	132	75%				
18 . . .	Can	154	88%	+	2.0:1	.49	.64
	Cannot	77	44%				
19 . . .	Can	155	88%	+	3.5:1	.63	.54
	Cannot	44	25%				
20 . . .	Can	164	93%	+	1.4:1	.43	.82
	Cannot	111	63%				
21 . . .	Can	33	19%	+	1.3:1	.08	.14
	Cannot	24	14%				
22 . . .	Can	128	73%	+	3.5:1	.53	.46
	Cannot	36	20%				
23 . . .	Can	143	81%	+	1.8:1	.40	.62
	Cannot	76	43%				
24 . . .	Can	174	99%	+	1.6:1	.68	.82
	Cannot	104	59%				
25 . . .	Can	136	77%	+	4.1:1	.57	.49
	Cannot	33	19%				
Part 3							
1 . . .	Can	142	81%	+	3.7:1	.58	.52
	Cannot	38	22%				
2 . . .	Can	127	72%	+	5.5:1	.60	.38
	Cannot	23	13%				
3 . . .	Can	29	16%	-	-0.7:1	-.10	.19
	Cannot	41	23%				
4 . . .	Can	154	88%	+	2.3:1	.54	.63
	Cannot	66	38%				
5 . . .	Can	147	84%	+	1.9:1	.44	.67
	Cannot	77	44%				
6 . . .	Can	123	70%	+	3.8:1	.53	.42
	Cannot	32	18%				

continued next page

TABLE 3.46--continued

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		p_{BIS}	Difficulty
		N	%	Direction	Ratio		
7 . . .	Can	147	84%	+	2.1:1	0.47	0.67
	Cannot	70	40%				
8 . . .	Can	74	42%	+	5.6:1	.47	.22
	Cannot	13	7%				
9 . . .	Can	166	94%	+	3.6:1	.71	.60
	Cannot	45	26%				
10 . . .	Can	57	32%	+	1.0:1	.01	.31
	Cannot	55	31%				
11 . . .	Can	80	45%	+	1.6:1	.18	.34
	Cannot	50	28%				
12 . . .	Can	142	81%	+	3.2:1	.56	.53
	Cannot	44	25%				
13 . . .	Can	57	32%	+	1.5:1	.12	.24
	Cannot	38	22%				
14 . . .	Can	144	82%	+	2.8:1	.54	.54
	Cannot	50	28%				
15 . . .	Can	148	84%	+	2.1:1	0.47	0.66
	Cannot	70	40%				
AVERAGES					2.6:1	0.46	0.52

Test 55, Year Ending Final Examination

Development of the Test

Test 55 was developed as an examination over the major areas of instruction for the year. Eight major areas were identified by the project director for consideration by the participants for the development of this examination. These areas did not parallel precisely the nine themes and objectives of the BSCS but do reflect them. Departures from the themes were made in accordance with the project director's perceptions of the patterns of instruction as developed during the year by the participating teachers.

To facilitate discussion and planning for Test 55 the project director prepared a table of the major areas with subsidiary topics of instruction. This table is reproduced in modified form as Table 3.47. Space was provided for assigning relative weights to each area for test development and for ranking the importance of the topics within each area. The percentage weight for each major area and the relative rank (1 is the highest rank) of the subsidiary topics as assigned by the participants are also included in Table 3.47. Following agreement on areas and topics, rating sheets for all of the tests used during the year with their included test questions were distributed. The participating teachers rated all questions on each of two criteria: the priority of the idea being tested by the question and the degree to which the question adequately assessed the idea.[1] In this way the questions rated highest on both criteria were selected for inclusion in Test 55 when

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[1] The rating sheet is not included in this report but is available on request to the project director.

TABLE 3.47

Major Areas of Understandings for Year Ending Final

AREAS	WEIGHT	TOPICS	RANK
1. SCIENCE AS ENQUIRY	15%	Theory: observation	3
		hypothesis	6
		assumption	1
		Experiment: description	2
		numerical	4
		graphic	5
2. HISTORY OF IDEAS	10%	Evolution: Lamarck Darwin	1
		biochemical	6
		populations	7
		Spontaneous Generation: Aristotle Von Helmont Redi Needham Pasteur Oparin	2
		Genetics: Mendel chromosomes	3
		one-gene one-enzyme	4
		populations	8
		Cell Theory	5
3. REGULATORY MECHANISMS	15%	Diffusion Osmosis	1
		Cell Metabolism	3
		Reproductive Cycles	3
		Body Temperature	6
		Excretion	4
		Digestive Enzyme Secretion	5
		Heart Rate	5
		Blood Glucose	5
		Plant Growth	5
		Photoperiodism	7
		Nerve Impulse and Nervous Control	2
		Respiratory Gases	4

TABLE 3.47--continued

AREAS	WEIGHT	TOPICS	RANK
4. EVOLUTION	15%	Heterotroph Hypothesis	1
		Variability	2
		Natural Selection	3
		Adaptations: structural physiological behavioral	4
		Phylogeny	1
5. GENETIC CONTINUITY	15%	Mendelian Genetics	4
		DNA: nature	5
		replication	2
		and meiosis	3
		code	3
		RNA-protein synthesis	1
		Genes and Enzymes	2
		Gene Pools and Gene Flow	3
6. ENERGY RELATIONSHIPS	15%	ATP-ADP Cycle	2
		Bond Energy: proteins fats carbohydrates	1
		Active Transport	5
		Muscle Contraction: ATP-ADP glycogen	3
		Enzyme Action	4
		Photosynthesis	6
7. GROWTH AND DEVELOPMENT	10%	Growth	1
		Differentiation	4
		Mitosis and Cell Division	3
		Nuclear-cytoplasmic Control	2
8. ECOLOGICAL RELATIONSHIPS	5%	Populations Societies Communities	
		Energy Relations	4
		Behavior	2
		Dynamics of Growth Succession	1
		Organisms in Groups	3

appropriate in terms of the priorities established. A miscellaneous area was added as the test was developed to include highly rated questions not assigned to the eight major areas. The teacher participants agreed that the year ending final examination should include many questions used on the instructional tests throughout the year and that new questions should be developed as needed to fulfill the weightings recommended. The suggested length of the test was to be approximately 45 questions.

The Test

The completed test contained 50 questions distributed as shown in Figure 3.16. This figure shows the nine areas of emphasis, the topic within each of these divisions, and the question numbers and their categorizations according to the Taxonomy as assigned by the project director. Questions which could be included in more than one category are placed in the category of their primary emphasis.

Using the terminology developed in the Taxonomy, 26 percent of the year ending final examination questions were classified by the project director as assessing aspects of knowledge (1.00) and 74 percent as assessing understandings and skills at the levels of comprehension, application, analysis and synthesis (2.00 and above). A copy of the test as given to the students in the test group follows.

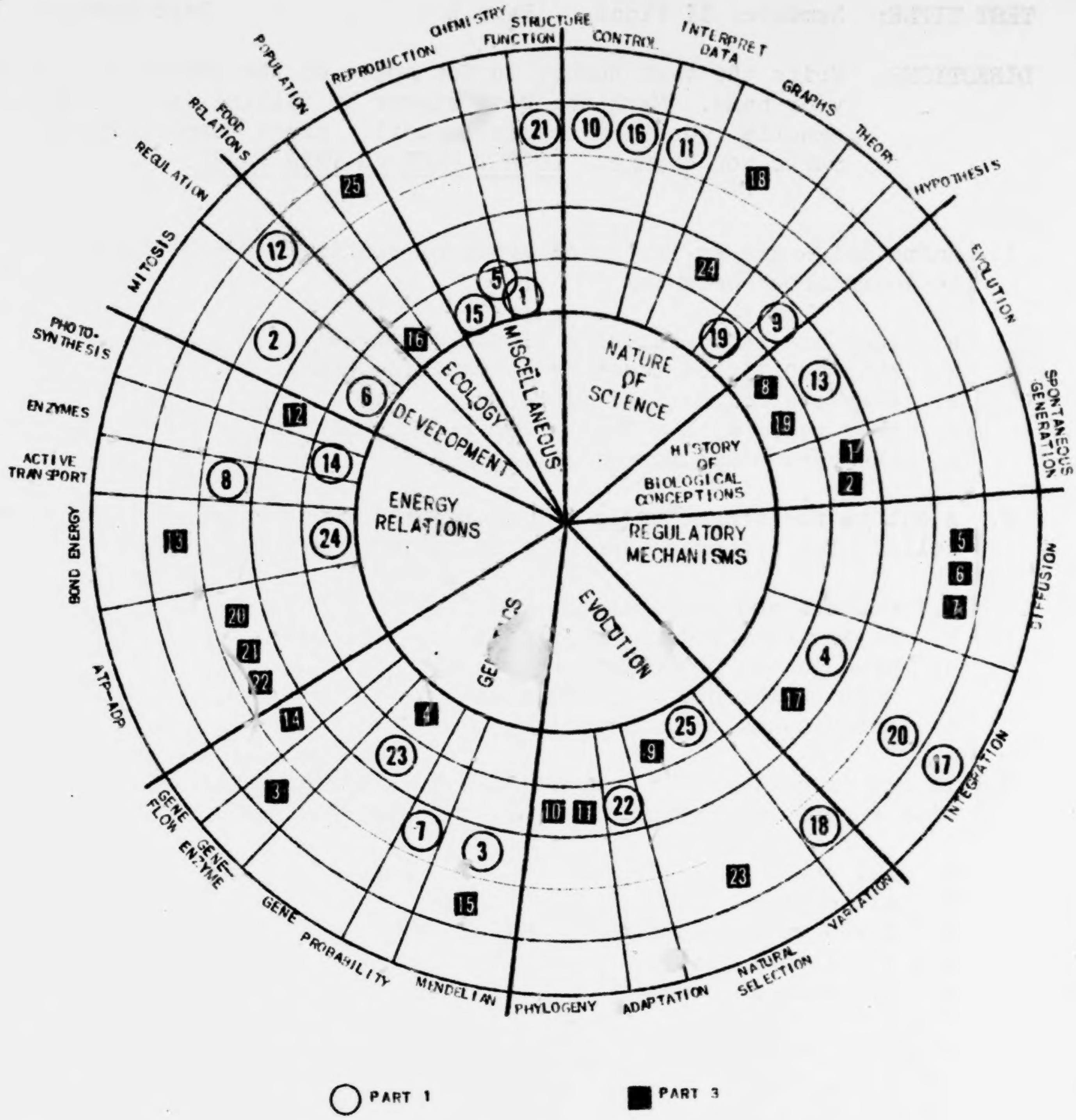


Fig. 3.16.--The Distribution of Questions on Test 55. The inner circle designates the nine major areas of emphasis of the test and the area's proportion of the test. The divisions of the major areas represent the proportion of each content area of the test. The concentric rings, beginning with the inner ring, represent categories 1.00, 2.00, 3.00, 4.00, and 5.00 of the Taxonomy.

TEST TITLE: Semester II Final Part 1 Test Number: 55

DIRECTIONS: Write the test number in the space on the answer card with your name. Mark the best answer by filling in the bubble exactly. Use the special pencil. Erase completely any marks you change. DO NOT MARK ON THIS PAPER.

1. Amino acids are an important group of chemicals for biologists to learn about because:

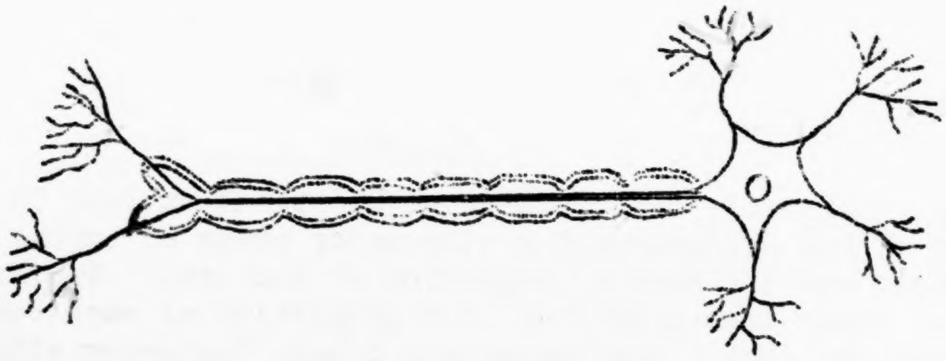
   a. they are basic building blocks of protein.
   b. they are linked together by pepetide bonds.
   c. they are composed of elements.
   d. they react with a large number of chemicals.
   e. they are compounds of nitrogen.

2. A cut on the finger kills or injures hundreds or even thousands of cells. The processes included in making new cells are:

   a. meiosis and respiration.
   b. respiration and photosynthesis.
   c. mitosis and photosynthesis.
   d. respiration and cell division.
   e. meiosis and cell division.

3. If red is dominant to orange and a pure orange organism is crossed with a pure red organism, the F_1 organism will be:

   a. all red.
   b. all orange.
   c. 1 red to 1 orange.
   d. 3 red to 1 orange.
   e. all reddish-orange.



4. The major function of the structure above is

   a. to secrete hormones.
   b. to transport chemical substances.
   c. to contract.
   d. to produce enzymes.
   e. to conduct impulses.

5. Variety in the characteristics of offspring depends primarily on

   a. reproduction.
   b. metamorphosis.
   c. meiosis.
   d. multiplication.
   e. mitosis.

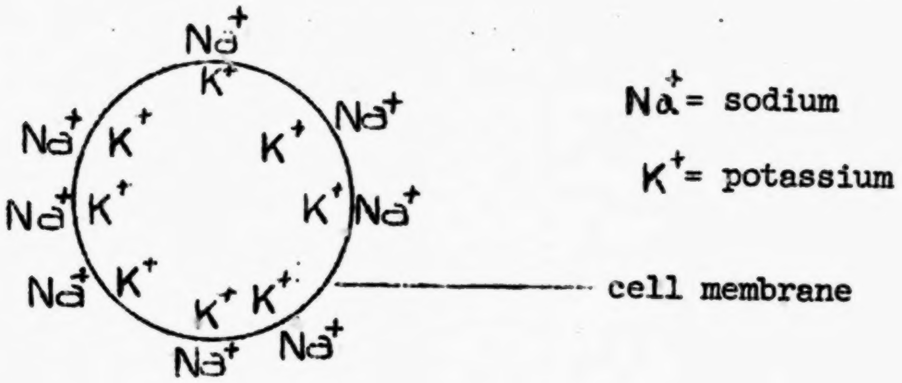
6. The development of organisms from fertilized egg to adult results from

   a. cell division.
   b. growth.
   c. differentiation.
   d. growth and differentiation.
   e. cell division, growth, differentiation.

7. If one kind of event has a chance happening (probability) of 1 in 4 and a second kind of event has a chance happening (probability) of 1 in 5, the chance (probability) that these two events will happen together is

   a. 1 in 4.
   b. 1 in 5.
   c. 1 in 9.
   d. 1 in 20.
   e. 1 in 25.

8. If the concentration of ions is maintained as in the following diagram for a long period of time we would assume that:



   a. energy is being expended (used).
   b. energy is being released.
   c. diffusion is occurring.
   d. the cell has died.
   e. energy is not involved in the process.

9. As developed in our laboratory work, one of the major functions of hypothesis is

   a. to make each experiment have the same form as the others.
   b. to determine the only way in which the experiment is done.
   c. to suggest the data to be collected.
   d. to give correct solutions.
   e. to make the experiment come out according to what is known to be true.

-3-*

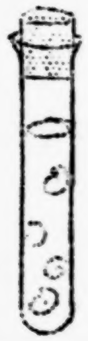
On the basis of the following discussion, answer questions 10 to 11.

Bromthymol blue is an acid-base indicator:

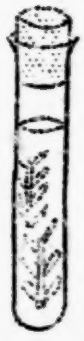
yellow in the presence of an acid
blue-green in a neutral solution
blue in the presence of a base

Carbon dioxide is a gas produced by living things after the breakdown of certain substances in their bodies. When dissolved in water, carbon dioxide produces an acid reaction in the presence of acid-base indicators.

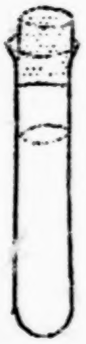
In order to find out if both green plants and animals produce carbon dioxide, three test tubes with similar amounts of blue-green colored bromthymol blue and water were placed on a test tube rack. Tube C was sealed. Several water snails were placed in tube A, several pieces of a water plant were placed in tube B, and each tube was sealed. All three tubes were placed in a lighted room. Three hours later, the bromthymol in tube A was yellow, in tube B was blue, and in tube C was blue-green.



Tube A



Tube B



Tube C

10. The "control" tube (or tubes) in this experiment

    a. is tube A.
    b. is tube B.
    c. is tube C.
    d. are tubes A and B.
    e. is missing.

11. The data collected as a result of the experiment were

    a. bromthymol blue is yellow in the presence of an acid and blue in the presence of a base.
    b. tubes with snails change bromthymol blue to a yellow color and tubes with green plants to a blue color.
    c. water snails produce carbon dioxide under conditions in which green water plants do not produce carbon dioxide.
    d. green water plants produce carbon dioxide under conditions in which water snails do not produce carbon dioxide.
    e. carbon dioxide gas produces color changes in bromthymol blue.

-4-*

12. Experimental evidence indicates that the

    a. genes act alone in determining the characteristics of the adult organism.
    b. the cytoplasm is responsible for as many genetic factors as the genes in determining the characteristics of the adult organism.
    c. the genes and the cytoplasm act together in determining the characteristics of the adult organism.
    d. the genes, the cytoplasm, and the environment act together in determining the characteristics of the adult organism.
    e. the environment is more important than the genes in determining the characteristics of the adult organism.

The following question is based upon this situation:

> The great auk, which became extinct in 1844, was the only bird in the northern hemisphere which could not fly. It lost the power of flight through disuse of its wings.

13. "It lost the power of flight through disuse of its wings," would be an explanation made by:

    a. Darwin.
    b. DeVries.
    c. Malthus.
    d. Mendel.
    e. Lamarck.

14. When enzymes are described as catalysts, we mean that

    a. they are proteins.
    b. they are produced by living cells.
    c. they change the rate of chemical reactions.
    d. they are used up in chemical reactions.
    e. they are essential to living organisms.

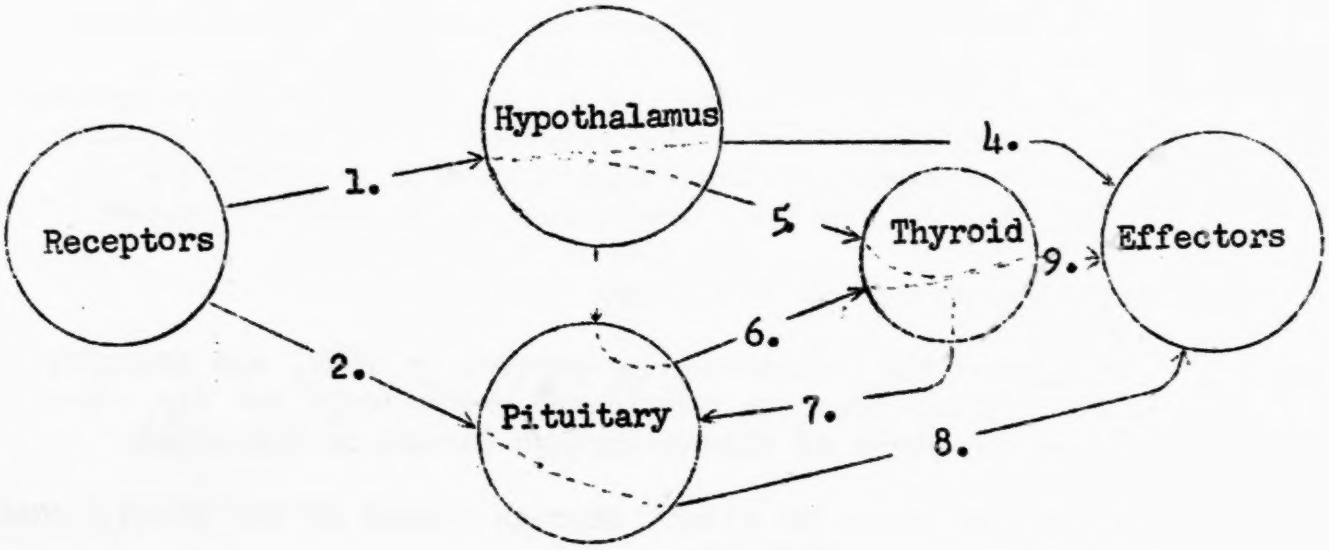
15. A nuclear event necessary for sexual reproduction is

    a. the development of a new individual from a single cell.
    b. illustrated by the development of a willow tree from a cutting.
    c. the fusion of the nuclei of two gametes.
    d. the creation of a new individual through meiosis from the doubling of the number of chromosomes.
    e. the separation of chromosomes through mitosis.

16. A control in an experiment is the

    a. point at which the experimenter makes observations.
    b. standard against which the experimenter measures the outcome of the experiment.
    c. careful measurement and record keeping of the experimenter.
    d. part in which the experimenter introduces variables.
    e. statement of the problem of the experiment.

-5-[*]



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[*] Because of the page break previously referred to, the question to this illustration appears on the following page.

17. The major significance to organisms of the interrelations shown above is that it illustrates

    a. regulation of temperature.
    b. regulation of the reproductive cycle.
    c. regulation by nervous and hormonal mechanisms.
    d. the general pathways of energy changes.
    e. the general pathways affecting growth and development.

18. Genetic variations may develop in a single organism in two main ways:

    a. gene flow and geographic isolation.
    b. migration and geographical isolation.
    c. mutations and chromosome changes.
    d. heredity and environment.
    e. natural selection and evolution.

19. Four of the following statements are accurate statements about theory. Which one is not an accurate statement about theory?

    a. Theories must be tested against accumulated knowledge.
    b. Theories are frequently revised as new knowledge becomes available.
    c. Theories are of greater interest to science as they are able to explain more and more.
    d. A theory shows what are the purposes, meanings, and values of life.
    e. A theory is developed to account for a body of knowledge.

20. Thyroxine and estrogen act in a similar way in that both

    a. influence cells all over the body.
    b. regulate a part of the reproductive cycle.
    c. feedback to a gland and inhibit specific hormone production.
    d. regulate the use of oxygen by cells.
    e. are carried by red blood cells.

21. Most of the conservation of water in the human body is accomplished by:

    a. the lungs and the kidneys.
    b. the kidneys and the small intestines.
    c. the small intestines and the lungs.
    d. the large intestines and the small intestines.
    e. the kidneys and the large intestines.

22. Four of the statements below are correct meanings of the term adaptation. Which statement is not a correct meaning of this term as it is understood today?

    a. It results from characteristics which improve the chances of a living thing to survive.
    b. It results from natural selection.
    c. It results from the changes made during the lifetime of an organism to meet the necessary conditions for life in its environment.
    d. The ancestors of a living thing had characteristics which allowed them to live and reproduce more effectively than similar ancestors without these characteristics.
    e. As a result of natural selection, most members of a species come to have characteristics which best allow them to survive in a given environment.

23. A knowledge of DNA is important in understanding living things because DNA

    a. serves as an enzyme in all known organisms.
    b. carries the genetic coding from parent to offspring.
    c. is the complex chemical which is essential for life.
    d. is found in the nucleus of cells in neurospore.
    e. is a spiral shaped molecule.

24. The energy which can be used by living things exists as:

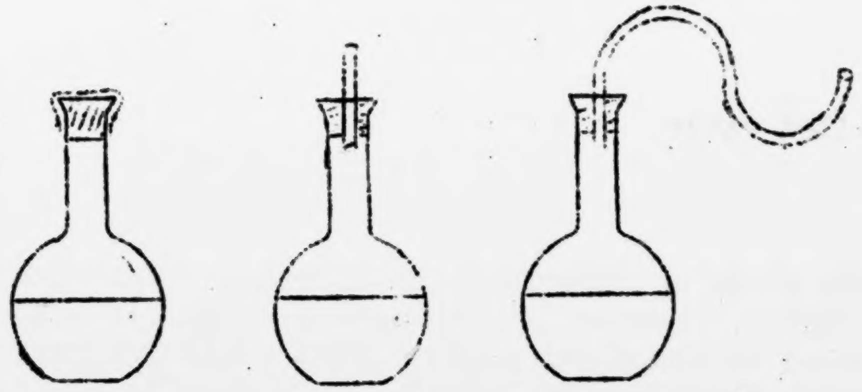
    a. the energy of the nucleus of the atom.
    b. the energy that bonds one atom to another.
    c. the energy of motion which all atoms possess.
    d. the energy stored in their molecules in the form of heat.

25. Darwin would have expected new species to be formed most rapidly in a

    a. large continental area in which geographical and geological features have stayed the same over long periods of time.
    b. small isolated island well stocked with many different forms of life.
    c. thinly populated region in which the conditions of life are the same everywhere.
    d. large continental area with different geological features.
    e. desert island with a small number of forms of life.

TEST TITLE: Semester II Final Part 3 Test Number: 55

DIRECTIONS: Write the test number in the space on the answer card with your name. Mark the best answer by filling in the bubble exactly. Use the special pencil. Erase completely any marks you change. DO NOT MARK ON THIS PAPER.



1. The experiment represented above was first done by:

    a. Darwin.
    b. Needham.
    c. Redi.
    d. Pasteur.
    e. Oparin.

2. The experiments performed with the apparatus above were responsible for the downfall of the

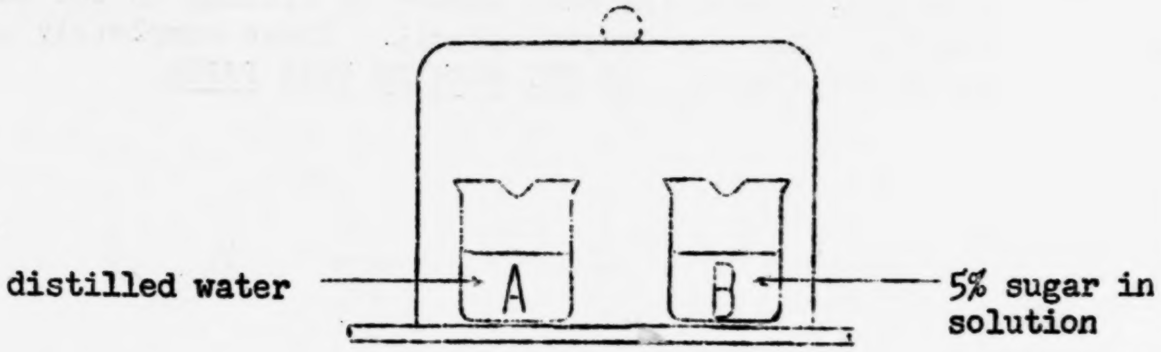
    a. germ theory of disease.
    b. theory of spontaneous generation.
    c. Lamarckian theory of evolution.
    d. theory of biogenesis.
    e. Darwin's theory of evolution.

3. In living things genes act by:

    a. moving from the nucleus to the cytoplasm where they form enzymes.
    b. directly controlling the ADP-ATP cycle.
    c. only in the cells of the embryo before differentiation.
    d. changing their code as cell differentiation progresses.
    e. the enzymes they pattern.

4. Mutations are basically the result changes in

    a. the DNA code.
    b. ribosome RNA.
    c. proteins.
    d. the cell cytoplasm.
    e. transfer RNA.



The diagram shows an experiment as it was set up. Beaker "A" contains distilled water. Beaker "B" contains 5% sugar in solution. The bell jar is sealed to the glass plate. What would you predict that you would observe three months later?

For each statement below (questions 5 to 7) select from the following key the most appropriate phrase:

a. The prediction is likely and the reason is true.
b. The statement is not likely and the reason is false.
c. The statement is not likely but the reason is an accepted fact or generalization.

5. The level in beaker "A" and "B" is the same as when the experiment was set up. REASON: Without a direct connection between the beakers no movement of molecules could occur.

6. The level in both beakers has decreased. REASON: Water molecules from each beaker moved until an equilibrium was reached in the bell jar, while the sugar molecules remained in beaker "B."

7. The level in beaker "A" decreased and the level in beaker "B" increased. REASON: Molecules move from regions of their higher concentration to regions of their lower concentration.

8. One of the following statements had been well developed and was known to Darwin at the time of his work:

a. The science of comparative embryology.
b. the findings of Mendel on inheritance.
c. the classification system of Linnaeus.
d. the science of paleontology which had revealed many fossils that could be arranged in a series.
e. the application of mathematics to evolution.

9. One of the following does not operate in natural selection:

   a. food supply.
   b. availability of mates.
   c. man's needs and purposes.
   d. inheritable differences.
   e. amount of sunlight.

-3-*

Groups of Mammals / Environmental Adaptations	Metatheria	Eutheria		
	Pouched Mammals	Placental Mammals		
		Unguiculata	Glires	Ferungulata
		Mammals with nails or claws	Gnawing Mammals	Carnivores and hoofed mammals
AQUATIC 1.Streamlined body 2.Webbed feet	water opossum	water shrew	beaver	seal
BURROWING 1.Burrowing feet 2.Short legs	banded anteater	golden mole	pocket gopher	badger
RUNNING 1.Large eyes & ears 2.Elevated head	kangaroo	baboon	rabbit	coyote
TREE-LIVING 1.Prehensile tail 2.Opposable thumb	koala	two-toed sloth	porcupine	lesser panda

USE the chart above in answering questions 10 and 11.

10. Of the animals grouped below, which are the more closely related, i.e., which have a greater number of similar genes?

    a. Water opossum and water shrew.
    b. Kangaroo and koala.
    c. Banded anteater and badger.
    d. Lesser panda and water opossum.
    e. Coyote and two-toed sloth.

11. Of the animals grouped below, which are the best examples of convergent evolution?

    a. Koala and water opossum.
    b. Banded anteater and lesser panda.
    c. Coyote and rabbit.
    d. Seal and baboon.
    e. Water shrew and golden mole.

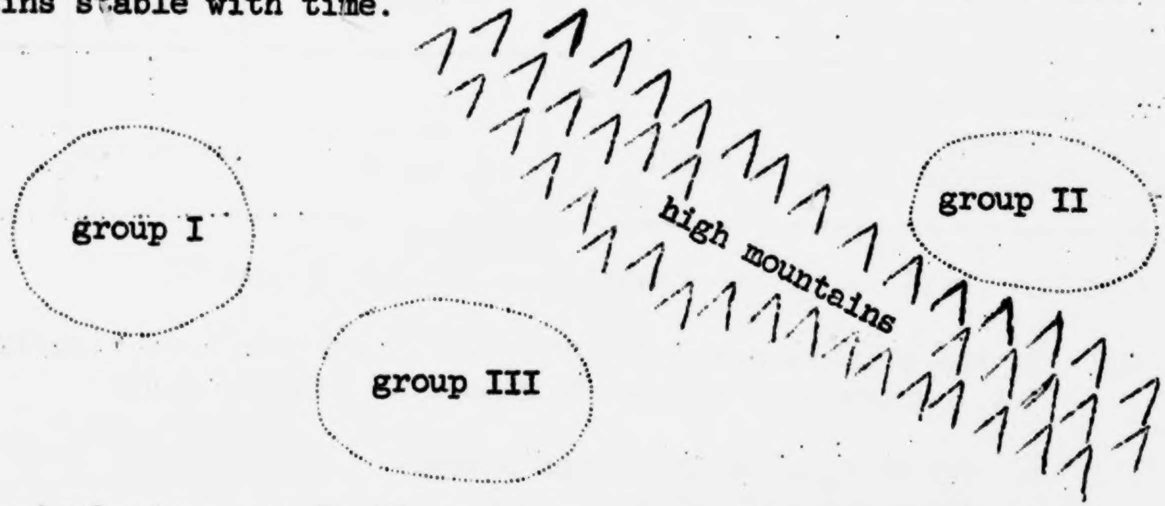
12. The energy in foods used by living things can be traced all the way back to

    a. light energy.
    b. chemical energy.
    c. heat energy.
    d. mechanical energy.
    e. electrical energy.

13. In general plants and animals are similar in that they both

    a. change light energy into the chemical bond energy of carbohydrates.
    b. release the chemical bond energy of carbohydrates and use up atmospheric oxygen in the process.
    c. are able to trap light energy in building carbohydrates.
    d. require a source of carbon dioxide to build up carbohydrates.

14. Biologists marked three groups of a single species of mammals found in geographical areas as shown below. They found that there was mating between animals of group I and group III but not between those in group I and II or II and III. The geography remains stable with time.



The animals in group I, II, and III are of the same species and

    a. form three genetic populations.
    b. form two genetic populations.
    c. form one genetic population.
    d. form part of one genetic population.
    e. cannot be considered as a genetic population.

15. A rare type of blindness is due to a dominant gene. What is the probability that two parents with normal vision will have children with this rare type of blindness?

    a. 1:1.
    b. 1:2.
    c. 1:3.
    d. 1:4.
    e. no chance.

16. Within a biological community some organisms are known as "producers" because they

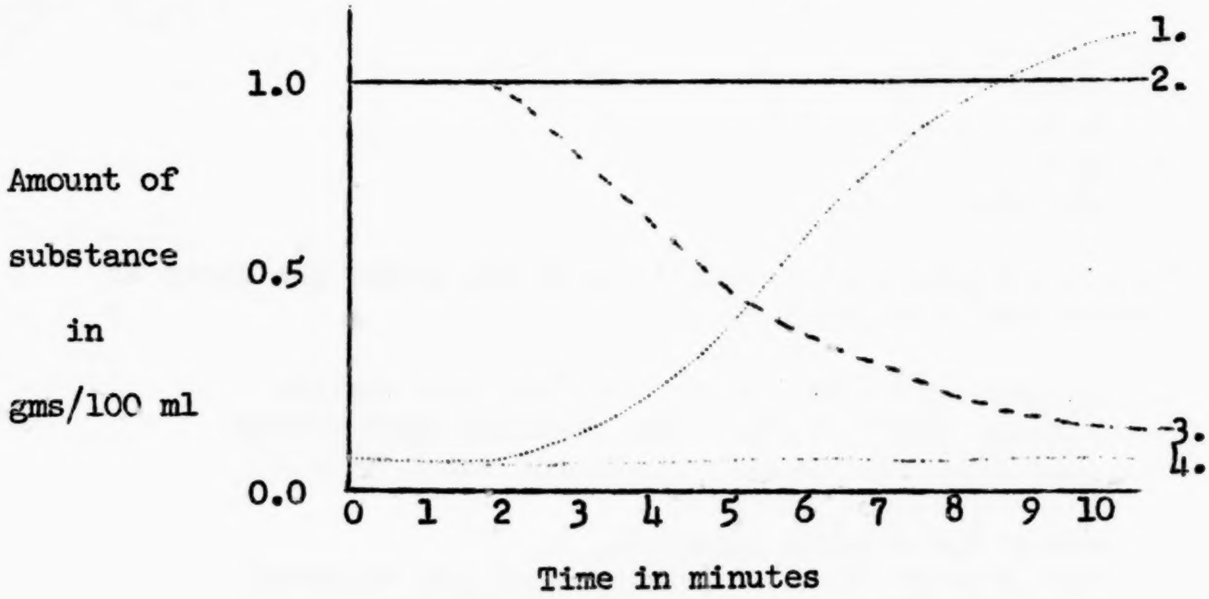
    a. produce the competition for food and shelter.
    b. convert light energy into chemical bond energy.
    c. prey upon the smaller organisms which have a high reproductive rate.
    d. decay the organic material.
    e. are present in small numbers and are consumed by most other members of the community.

-5-*

17. One of the following statements is the basic reason why biologists believe that nervous regulation and hormonal regulation are basically similar:

    a. After an impulse has passed a given point, the cell membrane recovers and polarization is restored.
    b. If a second stimulus is given immediately after the first, the nerve fiber does not respond.
    c. The cell membranes form barriers between nerve cells.
    d. Involve chemical substances which pass across the space between the cells and can activate muscles, glands, and nerve cells.
    e. The axons and dendrites of the nerve cells do not meet.

Urease is an enzyme which affects the breakdown of urea into ammonia. Use the graph below in answering question 18.

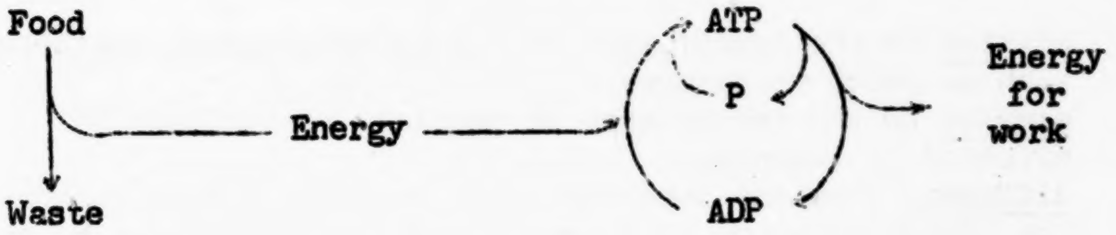


18. If 0.5 gms of urease were added at 2 minutes on the graph, which line would best represent the amount of urea?

    a. 1.
    b. 2.
    c. 3.
    d. 4.

19. One of the following statements does not correctly tell of the historical background of the theory of organic evolution:

    a. Greeks like Aristotle discussed the way in which life forms changed.
    b. Darwin's grandfather was the first to propose this idea.
    c. Lamarck proposed a theory of evolution before Charles Darwin.
    d. During the 16th and 17th century, some scholars thought of the possibility of evolution but rejected the idea.
    e. Some scholars of the 16th and 17th century thought that the species were unchangeable.



Use the diagram above to answer the next three questions (20 to 22).

20. In the diagram

    a. ATP has more usable energy than ADP.
    b. ADP loses a phosphate and gains energy.
    c. Energy from food is used directly for work.
    d. ATP has less usable energy than ADP.
    e. Waste materials provide a source of energy for work.

21. Which of the following best states the importance to understanding how organisms function? (Refer to the diagram above.)

    a. It shows that foods are used by organisms.
    b. It shows how energy for work in man is obtained from ATP.
    c. It applies to most organisms studied and indicates the function of ATP.
    d. It applies to processes in living cells.

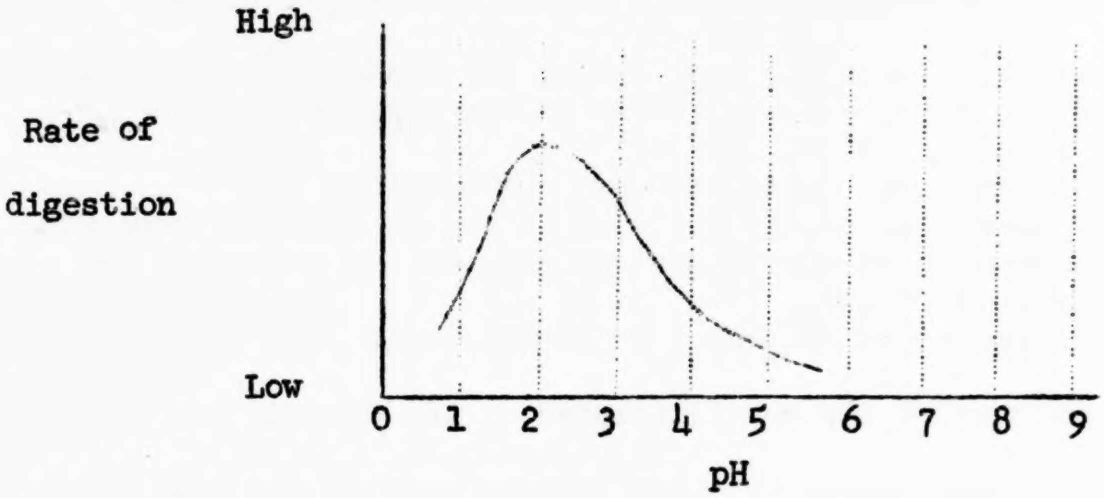
22. The function of ATP as illustrated in the diagram is:

    a. It stores energy from the working part of the body which it then releases by its breakdown to ADP.
    b. It removes energy from food.
    c. It transfers energy from food by means of a phosphate bond and releases this energy as required by the organism.
    d. It transfers energy to ADP which is then released by ADP as required by the organism.

23. Even complex patterns of behavior in many animals are believed to be inherited and based the gene pool of the species. The best explanation for the manner in which such behavior traits become a part of the gene pool is:

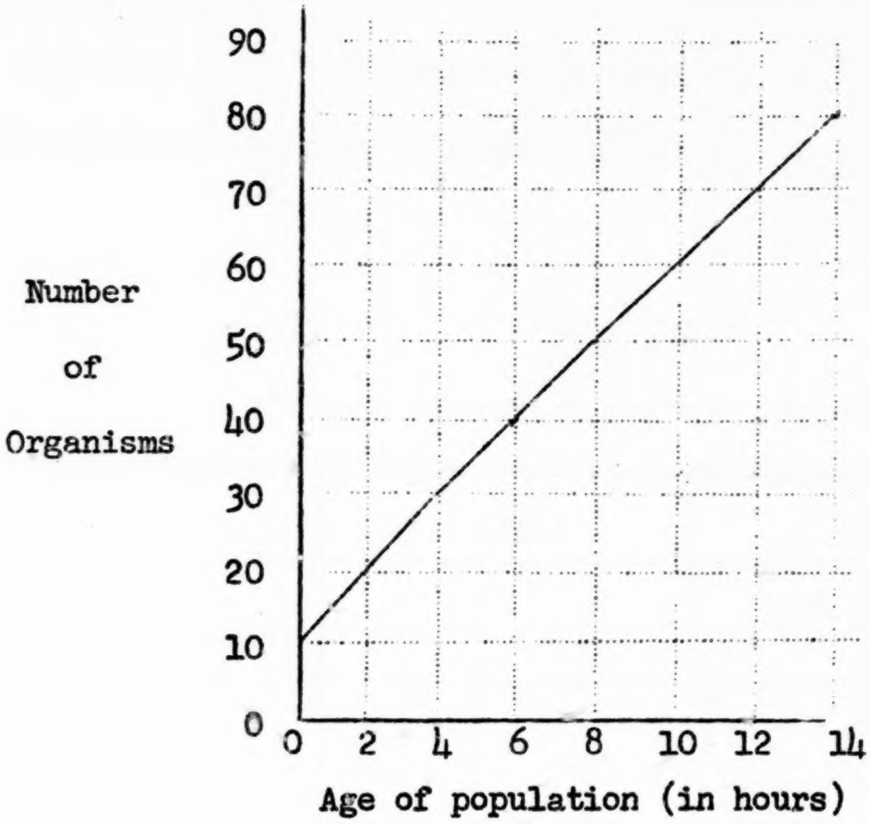
a. similar to the inheritance of traits of physical features such as tooth structures.
b. similar to the inheritance of physical traits, but is affected by learning.
c. different from the inheritance of physical traits in that the behavior has to be learned first, before it can become a part of the gene pool.
d. different from the inheritance of physical traits in that natural selection does not affect behavioral traits.
e. different from the inheritance of physical traits in that behavioral patterns cannot be carried by DNA.

-7-*



24. The enzyme action shown on the graph above will digest foods faster at pH

a. 1.
b. 2.
c. 3.
d. 4.
e. 5.



25. The rate of growth of the population above is

- a. increasing with time.
- b. remaining the same with time.
- c. decreasing with time.
- d. changing with time.
- e. unstable with time.

Analysis of Test Results

Table 3.48 shows the frequency of total correct responses for the 656 students taking Test 55. The mean achievement for these students was 29.8 raw score points, or 60 percent, and the standard deviation was 7.9 raw score points.

TABLE 3.48

Distribution of Correct Scores for Test 55

NUMBER OF CORRECT CHOICES*	BOYS		GIRLS		TOTAL	
	Frequency	Per-centage	Frequency	Per-centage	Frequency	Per-centage
44-45 . . .	9	2.7	7	2.1	16	2.4
42-43 . . .	13	3.9	8	2.4	21	3.2
40-41 . . .	17	5.1	13	4.0	30	4.6
38-39 . . .	21	6.3	21	6.5	42	6.4
36-37 . . .	27	8.1	25	7.7	52	8.0
34-35 . . .	16	4.8	28	5.5	34	5.2
32-33 . . .	32	9.6	25	7.7	57	8.7
30-31 . . .	27	8.1	36	11.1	63	9.6
28-29 . . .	29	8.7	39	12.0	68	10.3
26-27 . . .	26	7.8	27	8.3	53	8.1
24-25 . . .	25	7.5	18	5.6	43	6.5
22-23 . . .	28	8.4	20	6.2	48	7.3
20-21 . . .	22	6.6	24	7.4	46	7.0
18-19 . . .	13	3.9	22	6.8	35	5.3
16-17 . . .	11	3.3	6	1.8	17	2.6
14-15 . . .	8	2.4	7	2.1	15	2.3
12-13 . . .	5	1.5	8	2.4	13	2.0
10-11 . . .	1	0.3	0	0.0	1	0.2
8- 9 . . .	1	0.3	1	0.3	2	0.3
TOTALS	331	99.3	325	99.9	656	100.0

*50 is the maximum number possible.

Percentile scores of the DAT (VR + NA) for the Test Group, Cans, and Cannots are shown in Figure 3.17. The median score for the Cans falls above the 90th percentile, for the Test Group at about the 60th percentile, and for the Cannots at about the 40th percentile.

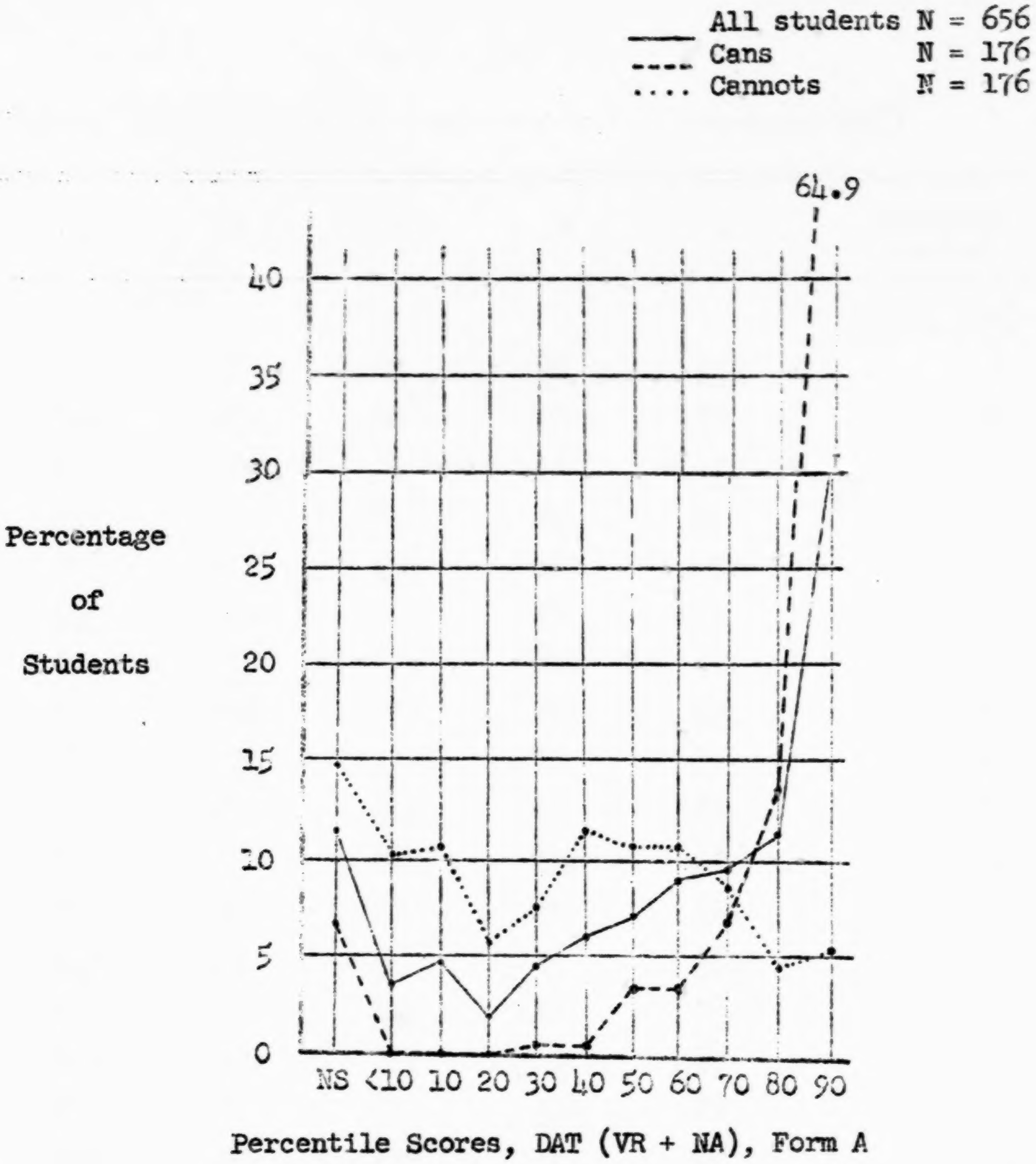


Fig. 3.17.--Frequency distributions for students taking Test 55 by publisher's percentile scores on the DAT (VR + NA).

A detailed response pattern of students taking Test 55 is shown in the item analysis presented in Table 3.49, and the item responses for the Cans and Cannots are presented in Tables 3.50 and 3.51 respectively. Data for the discussion which follows were obtained from these tables.

TABLE 3.49

Item Responses to the Questions on Test 55: Test Group*

Question Number	a	b	c	d	e	Omit
Part 1						
1	93%	2%	2%	3%	. .	. .
2	4%	2%	8%	45%	41%	1%
3	62%	2%	5%	25%	6%	. .
4	3%	3%	2%	1%	90%	1%
5	22%	8%	57%	3%	9%	1%
6	4%	6%	1%	10%	79%	. .
7	. .	1%	13%	85%	1%	.
8	34%	12%	12%	20%	21%	1%
9	4%	5%	67%	12%	12%	1%
10	1%	3%	93%	2%	1%	. .
11	5%	33%	45%	8%	9%	1%
12	12%	3%	7%	72%	5%	1%
13	23%	3%	5%	5%	62%	1%
14	8%	5%	72%	9%	6%	. .
15	5%	2%	55%	24%	13%	. .
16	2%	87%	2%	7%	1%	. .
17	6%	3%	68%	4%	19%	1%
18	6%	5%	57%	19%	12%	1%
19	4%	7%	7%	77%	5%	. .
20	10%	22%	52%	7%	8%	1%

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*Expressed as a percentage of N. N = 656. —— Correct response.

TABLE 3.49--*continued*

Question Number	a	b	c	d	e	Omit
21	10%	35%	3%	6%	46%	1%
22	5%	17%	43%	30%	4%	1%
23	4%	66%	28%	2%	1%	. .
24	9%	69%	8%	13%	. .	. .
25	9%	29%	3%	53%	6%	1%
Part 3						
1	2%	7%	14%	73%	4%	. .
2	10%	80%	3%	5%	. .	1%
3	11%	14%	16%	14%	44%	1%
4	75%	5%	3%	6%	11%	. .
5	23%	63%	11%	. .	1%	1%
6	31%	50%	17%	. .	1%	1%
7	20%	26%	53%	. .	1%	1%
8	4%	11%	59%	17%	7%	.
9	4%	7%	53%	10%	25%	1%
10	29%	58%	8%	2%	3%	. .
11	13%	7%	52%	5%	23%	. .
12	77%	12%	9%	1%	1%	. .
13	14%	44%	10%	30%	. .	1%
14	11%	70%	7%	5%	6%	1%
15	2%	4%	2%	13%	79%	1%
16	19%	48%	9%	6%	18%	1%
17	12%	11%	7%	65%	5%	. .
18	34%	6%	55%	4%	. .	1%
19	15%	48%	16%	14%	6%	1%
20	67%	14%	7%	9%	2%	1%
21	8%	24%	42%	25%	. .	1%
22	26%	6%	58%	9%	. .	. .
23	22%	41%	19%	8%	9%	1%
24	6%	87%	3%	1%	2%	. .
25	66%	25%	4%	4%	. .	1%

TABLE 3.50

Item Responses to the Questions on Test 55: Cans*

Question Number	a	b	c	d	e	Omit
Part 1						
1	99%	. .	. .	1%	. .	. .
2	1%	. .	5%	78%	16%	. .
3	85%	1%	1%	11%	2%	. .
4	. .	. .	. .	. .	99%	1%
5	15%	3%	77%	1%	3%	1%
6	2%	1%	. .	2%	94%	. .
7	. .	. .	1%	99%	1%	. .
8	65%	3%	1%	19%	11%	1%
9	2%	2%	85%	6%	5%	. .
10	1%	. .	99%	. .	1%	. .
11	1%	52%	45%	2%	. .	1%
12	6%	. .	3%	89%	2%	. .
13	9%	1%	1%	. .	89%	1%
14	2%	. .	96%	2%	1%	. .
15	1%	. .	82%	12%	6%	. .
16	. .	99%	. .	1%	. .	. .
17	6%	. .	83%	1%	11%	. .
18	5%	5%	80%	6%	5%	. .
19	1%	3%	2%	93%	2%	. .
20	3%	11%	81%	. .	5%	. .
21	5%	16%	. .	3%	75%	1%
22	2%	2%	80%	13%	2%	1%
23	1%	84%	14%	1%	1%	. .
24	. .	98%	1%	2%	. .	. .
25	2%	25%	1%	67%	5%	1%

continued next page

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*Expressed as a percentage of N. N = 176. —— Correct response.

TABLE 3.50--*continued*

Question Number	a	b	c	d	e	Omit
Part 3						
1	1%	3%	2%	93%	1%	. .
2	1%	98%	1%	1%	. .	1%
3	7%	4%	6%	4%	79%	. .
4	94%	3%	. .	. .	3%	. .
5	20%	70%	8%	. .	1%	1%
6	37%	53%	10%	. .	1%	1%
7	19%	20%	61%	. .	. .	. .
8	1%	6%	85%	6%	1%	. .
9	1%	3%	85%	1%	10%	. .
10	14%	84%	1%	. .	1%	. .
11	9%	2%	81%	. .	9%	. .
12	96%	2%	1%	. .	1%	. .
13	5%	64%	3%	27%	. .	1%
14	5%	89%	3%	1%	1%	1%
15	. .	. .	. .	4%	96%	. .
16	5%	80%	2%	2%	10%	. .
17	. .	1%	3%	91%	5%	. .
18	15%	2%	81%	2%	. .	1%
19	18%	51%	11%	16%	4%	. .
20	92%	2%	2%	4%	. .	. .
21	6%	8%	60%	26%	. .	. .
22	18%	1%	78%	2%	. .	. .
23	44%	39%	8%	1%	7%	1%
24	2%	98%	. .	. .	. .	. .
25	48%	47%	3%	2%	. .	. .

TABLE 3.51

Item Responses to the Questions on Test 55: Cannots*

Question Number	a	b	c	d	e	Omit
Part 1						
1	80%	6%	4%	9%	1%	1%
2	7%	5%	7%	24%	55%	2%
3	34%	5%	12%	38%	12%	1%
4	10%	11%	5%	3%	68%	2%
5	33%	15%	32%	6%	13%	1%
6	6%	13%	3%	18%	60%	1%
7	1%	3%	34%	61%	1%	1%
8	17%	22%	22%	16%	22%	2%
9	5%	9%	39%	23%	22%	2%
10	2%	10%	80%	5%	3%	1%
11	13%	16%	31%	19%	19%	3%
12	17%	10%	14%	45%	13%	2%
13	40%	4%	12%	13%	30%	2%
14	15%	12%	43%	15%	15%	1%
15	10%	6%	34%	34%	16%	1%
16	7%	61%	7%	20%	4%	1%
17	2%	8%	55%	10%	23%	2%
18	7%	9%	30%	36%	16%	2%
19	7%	14%	17%	51%	11%	1%
20	11%	18%	36%	18%	16%	1%
21	13%	45%	6%	11%	23%	2%
22	10%	28%	18%	38%	6%	1%
23	9%	39%	45%	4%	1%	2%
24	18%	35%	20%	26%	1%	1%
25	19%	31%	7%	34%	7%	1%

continued next page

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*Expressed as a percentage of N. N = 176. —— Correct response.

TABLE 3.51--*continued*

Question Number	a	b	c	d	e	Omit
Part 3						
1	5%	10%	27%	*52%*	6%	1%
2	30%	*47%*	10%	11%	1%	1%
3	18%	22%	21%	19%	*18%*	2%
4	*44%*	12%	9%	16%	19%	.
5	20%	*53%*	22%	. .	2%	2%
6	33%	38%	*27%*	. .	1%	1%
7	*31%*	28%	39%	. .	1%	2%
8	7%	15%	*35%*	27%	15%	1%
9	11%	11%	*34%*	15%	26%	2%
10	45%	*28%*	17%	6%	4%	1%
11	14%	13%	*36%*	11%	24%	1%
12	*56%*	19%	19%	1%	4%	1%
13	19%	*31%*	16%	33%	1%	1%
14	14%	*48%*	13%	9%	15%	2%
15	7%	10%	5%	24%	*52%*	3%
16	24%	*26%*	19%	9%	22%	1%
17	20%	24%	17%	*34%*	5%	. .
18	42%	12%	*37%*	8%	1%	. .
19	16%	*40%*	23%	11%	8%	2%
20	*39%*	25%	15%	11%	6%	3%
21	11%	35%	*26%*	25%	2%	2%
22	25%	15%	*38%*	20%	2%	1%
23	*10%*	35%	28%	15%	10%	1%
24	8%	*72%*	10%	3%	7%	. .
25	76%	*11%*	6%	6%	. .	1%

This year ending examination will be analyzed in the same pattern as Test 48 in order to provide some opportunity for the reader to compare parallel data. The relative success of the Test Group, Cans, and Cannots for the nine areas of emphasis which were shown in Figure 3.16[1] is presented in Figure 3.18.

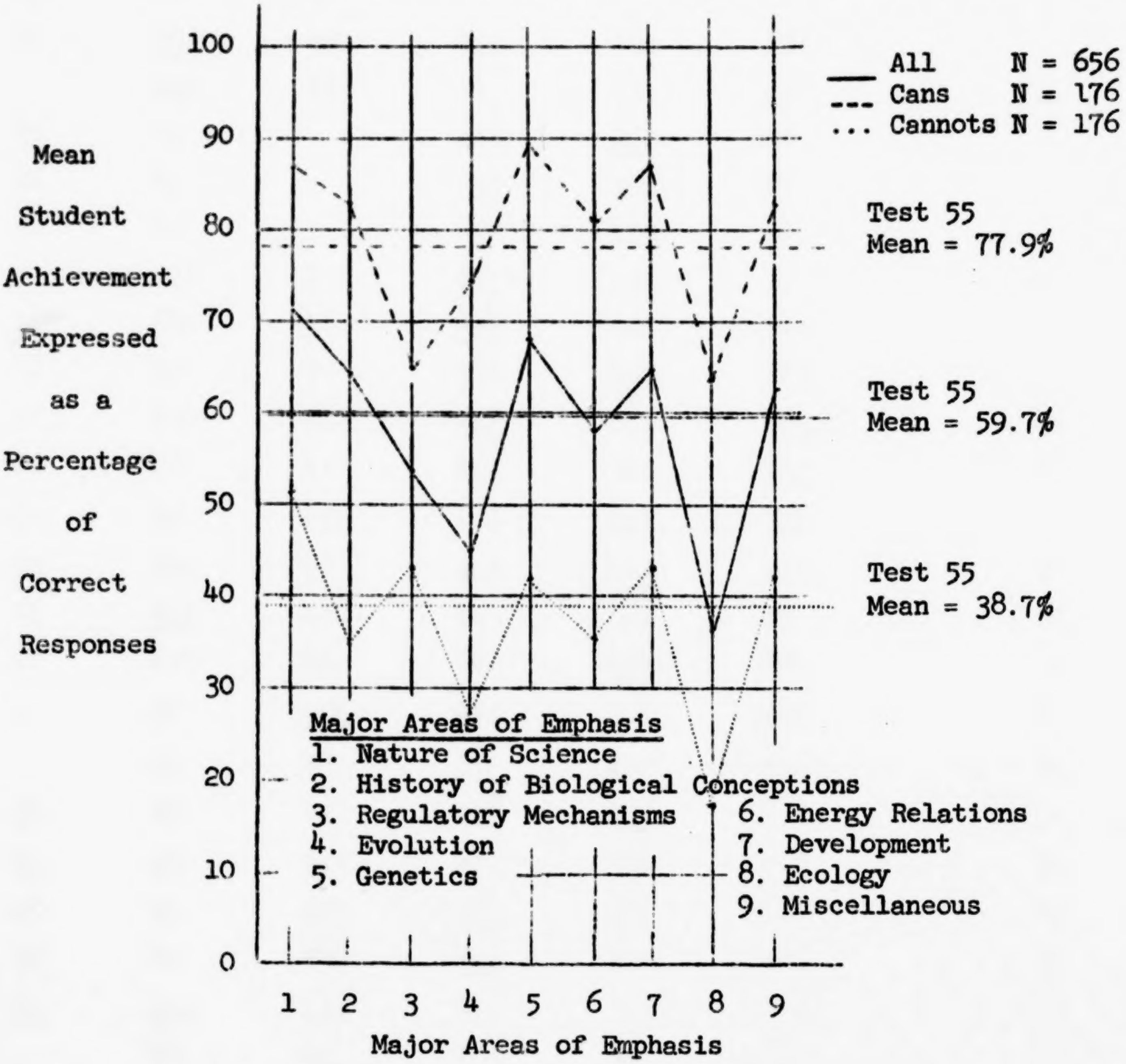

Fig. 3.18.--Percentage of Students in the Test Group, Cans, and Cannots Selecting the Best Responses to the Questions in the Nine Areas of Test 55.

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[1] See p. 259.

It will be noted that the mean achievement on the total test dropped about 20 percent from the Cans to the Test Group and another 20 percent from the Test Group to the Cannots. The differential between the mean of the Cans and the Test Group for the questions designed to assess the nature of science (emphasis area 1) was 16 percent; but, again, the drop from the Test Group to the Cannots was 20 percent.

Two questions in Test 55 were negative discriminators between the Cans and Cannots, and the remainder were positive discriminators. The mean difficulty was 0.60 and the mean biserial correlation was 0.47. Forty-two questions had biserial correlations of 0.40 or above, four had biserial correlations of 0.30-0.39, two had biserial correlations below 0.29, and two, as mentioned above, had negative biserial correlations. The discrimination ratios ranged from a high of 4.5:1 on question 22, Part 1, to a low of -0.6:1 on question 7, Part 3. Detailed data on the Can-Cannot analysis is presented in Table 3.52.

TABLE 3.52

Can-Cannot Analysis of Test 55

N = 656 Cans and Cannots each = 27% of N, or = 176

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		P_{BIS}	Difficulty
		N	%	Direction	Ratio		
Part 1							
1 . . .	Can	174	99%	+	1.2:1	0.53	0.93
	Cannot	141	80%				
2 . . .	Can	137	78%	+	3.1:1	.54	.45
	Cannot	43	24%				
3 . . .	Can	150	85%	+	2.5:1	.53	.62
	Cannot	59	34%				
4 . . .	Can	175	99%	+	1.4:1	.63	.90
	Cannot	120	68%				
5 . . .	Can	136	77%	+	2.3:1	.46	.57
	Cannot	57	32%				
6 . . .	Can	166	94%	+	1.5:1	.48	.79
	Cannot	105	60%				
7 . . .	Can	174	99%	+	1.6:1	.67	.85
	Cannot	107	61%				
8 . . .	Can	115	65%	+	3.8:1	.49	.34
	Cannot	30	17%				
9 . . .	Can	150	85%	+	2.2:1	.49	.67
	Cannot	68	39%				
10 . . .	Can	174	99%	+	1.2:1	.53	.93
	Cannot	141	80%				
11 . . .	Can	91	52%	+	3.2:1	.40	.33
	Cannot	28	16%				
12 . . .	Can	156	89%	+	1.9:1	.50	.72
	Cannot	79	45%				
13 . . .	Can	157	89%	+	3.0:1	.61	.62
	Cannot	52	30%				
14 . . .	Can	169	96%	+	2.2:1	.65	.72
	Cannot	75	43%				

continued next page

TABLE 3.52--continued

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		PBIS	Difficulty
		N	%	Direction	Ratio		
15 . . .	Can	144	82%	+	1.5:1	0.49	0.55
	Cannot	59	34%				
16 . . .	Can	175	99%	+	1.6:1	.67	.87
	Cannot	108	61%				
17 . . .	Can	146	83%	+	1.5:1	.32	.68
	Cannot	96	55%				
18 . . .	Can	141	80%	+	2.7:1	.51	.57
	Cannot	52	30%				
19 . . .	Can	163	93%	+	1.8:1	.53	.77
	Cannot	90	51%				
20 . . .	Can	142	81%	+	2.2:1	.47	.52
	Cannot	63	36%				
21 . . .	Can	132	75%	+	3.3:1	.52	.46
	Cannot	40	23%				
22 . . .	Can	141	80%	+	4.5:1	.61	.43
	Cannot	31	18%				
23 . . .	Can	148	84%	+	2.1:1	.48	.66
	Cannot	68	39%				
24 . . .	Can	172	98%	+	2.8:1	.74	.69
	Cannot	61	35%				
25 . . .	Can	118	67%	+	1.9:1	.33	.53
	Cannot	60	34%				
Part 3							
1 . . .	Can	163	93%	+	1.7:1	.53	.73
	Cannot	92	52%				
2 . . .	Can	172	98%	+	2.0:1	.69	.80
	Cannot	82	47%				
3 . . .	Can	139	79%	+	4.3:1	.60	.44
	Cannot	32	18%				
4 . . .	Can	165	94%	+	2.1:1	.60	.75
	Cannot	77	44%				
5 . . .	Can	124	70%	+	1.3:1	.18	.63
	Cannot	93	53%				

continued next page

TABLE 3.52--continued

	Frequency on Correct Answer			Discrimination		PBIS	Difficulty
		N	%	Direction	Ratio		
6 . . .	Can	17	10%	-	-0.3:1	-0.27	0.17
	Cannot	48	27%				
7 . . .	Can	33	19%	-	-0.6:1	- .16	.20
	Cannot	54	31%				
8 . . .	Can	150	85%	+	2.4:1	.52	.59
	Cannot	61	35%				
9 . . .	Can	149	85%	+	2.4:1	.53	.53
	Cannot	60	34%				
10 . . .	Can	148	84%	+	3.0:1	.57	.58
	Cannot	49	28%				
11 . . .	Can	143	81%	+	2.2:1	.47	.52
	Cannot	64	36%				
12 . . .	Can	169	96%	+	1.7:1	.57	.77
	Cannot	98	56%				
13 . . .	Can	113	64%	+	2.0:1	.34	.44
	Cannot	54	31%				
14 . . .	Can	157	89%	+	1.8:1	.48	.70
	Cannot	85	48%				
15 . . .	Can	169	96%	+	1.8:1	.60	.79
	Cannot	91	52%				
16 . . .	Can	141	80%	+	3.1:1	.54	.48
	Cannot	45	26%				
17 . . .	Can	161	91%	+	2.6:1	.61	.65
	Cannot	60	34%				
18 . . .	Can	142	81%	+	2.1:1	.46	.55
	Cannot	65	37%				
19 . . .	Can	90	51%	+	1.2:1	.11	.48
	Cannot	71	40%				
20 . . .	Can	162	92%	+	2.3:1	.59	.67
	Cannot	69	39%				
21 . . .	Can	106	60%	+	2.3:1	.35	.42
	Cannot	45	26%				
22 . . .	Can	138	78%	+	2.0:1	.42	.58
	Cannot	67	38%				

continued next page

TABLE 3.52--continued

QUESTION NUMBER	Frequency on Correct Answer			Discrimination		P_{BIS}	Difficulty
		N	%	Direction	Ratio		
23 . . .	Can	78	44%	+	4.3:1	0.43	0.22
	Cannot	18	10%				
24 . . .	Can	172	98%	+	1.3:1	.53	.87
	Cannot	127	72%				
25 . . .	Can	82	47%	+	4.1:1	0.44	0.25
	Cannot	20	11%				
AVERAGES	. . . .				2.2:1	0.47	0.59

Space will permit only a discussion of the questions designed to assess aspects of the nature of science. Seven questions were placed in this category.

Five questions were designed to assess interpretations of described experiments. Two of these questions (Q. 10 and Q 16 of Part 1) were designed to assess aspects of the students' understandings of control. Ninety-nine percent of the Cans responded correctly to both questions. Eighty percent of the Cannots were able to identify a control in the description of an experiment but success dropped to 61 percent when the question was concerned with control in the abstract. The Cannots selected the response the "part in which the experimenter introduces variables" as the major distractor. Identifying the data obtained from a described experiment was assessed by question 11 of Part 1. Fifty-two percent of the Cans, 33 percent of the Test Group, and 16 percent of the Cannots selected the correct response to this question. All of the distractors were interpretations in which an indicator color change was "observed" to be the presence of an acid or of carbon dioxide. Two questions (Q. 18 and Q. 24 of Part 3) were designed to assess the ability to interpret graphed data. Fifty-five percent of the Test Group, 81 percent of the Cans, and 37 percent of the Cannots selected the correct response to question 18. The major distractor for each group was a line showing the inverse of the correct response.

Question 19 of Part 1 was the only question of Test 55 which was developed to assess the nature of theory. Ninety-three percent of the Cans, 77 percent of the Test Group, and 51 percent of the Cannots selected the best response to this question. The major distractors for the Test Group and the Cannots were statements that theories were "not of greater interest to science as they are able to explain more" and that theories are "not frequently revised as new knowledge becomes available."

Question 9 of Part 1 was designed to assess the major function of hypothesis as developed in the students' laboratory work. Eighty-five percent of the Cans, 67 percent of the Test Group, and 39 percent of the Cannots selected the best response to this question. The major distractors of each group were "to give the correct solutions," and "to make the experiment come out according to what is known to be true." If this question is considered as an opionaire without a "best" response, 24 percent of the students taking Test 55 would be considered as stating that the two statements above characterize their laboratory experiences with hypotheses.

Only question 16 in this series on the nature of science was a new question to the students. Changes in the response patterns to the repeated questions through the course of the year will be considered in the final section of this report.

CHAPTER IV

ASPECTS OF THE READABILITY OF BLUE VERSION MATERIALS

Some Findings on the Readability of the 1961 and 1963 Editions of the Blue Version[1]

Data on the nature of the student population and the results of the instructional tests taken by the students in this study provide two essential elements for discussing student understandings of biology. A third element to be considered is the readability of the text materials used by the students. Concern with this factor developed from discussions with teachers participating in the Blue Version Test Center during 1961-62. Although the BSCS proposed an approximate 37 percent of class time for laboratory and 63 percent for text, quizes, tests, and reviews,[2] the participating teachers found that more time was needed for laboratory work, and especially for discussion of the laboratory work. This shift in time allocation made it necessary to assign text reading and study as out of class work. Comments by students and the quality of class discussions as reported by teachers reflected difficulties in the students' abilities to read and understand the text.

In order to assess the readability of the basic text material used by students in the study group, readability scores were determined by using two commonly used formulas: the Flesch Reading Ease Score (1948)[1] and the Dale-Chall Readability Score (1948).[2] Pages to be scored were selected by using a table of random numbers to secure a 10 percent sample of the 1961 edition of the Blue Version text (76 pages).

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[1] The writer wishes to acknowledge the assistance of Mrs. Elizabeth A. Pellett, Los Angeles County Schools Office, and Dr. Walter Loban, University of California at Berkeley, for their suggestions regarding readability assessment.

[2] *The Blue Version Laboratory Teachers' Guide*, Part 1, *op. cit.*, p. Ap-22.

In using the formulas several conventions were adopted due to the specialized nature of the material being assessed. In cases where the page included a large drawing with little context, or where study questions made up the page, the random number of the page was skipped and a new page was added from the table. Symbols such as DNA and ATP were counted as one word, and each letter was counted as a syllable where a syllable count was necessary. The number 1948, and similar numbers, was counted as four syllables with the Flesch formula, but was counted by its syllables when written-out with the Dale-Chall. Sentences with a colon were counted as two sentences on the Flesch readability scale and were counted as one sentence on the Dale-Chall scale except when the colon preceded a complete statement. The first complete paragraph on each page selected from the table of random numbers was selected for readability assessment. Thus, if a page began with a paragraph carried over from the preceding page, the paragraph selected for readability assessment was the first new paragraph on the page. If the paragraph began with a heading set out apart from the paragraph, the heading was not counted as a part of the readability study. Each paragraph studied was evaluated for each of the two readability scales.

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[1] As abridged in Research in the 3 Rs by C. W. Hunnicutt and William J. Iverson (New York: Harper and Brothers, 1958), pp. 194-213.

[2] Rudolf Flesch, How to Test Readability (New York: Harper and Brothers, 1951), pp. 1-10. (First published in The Art of Readable Writing, 1949.)

The results of the readability study are presented in Tables 4.1 and 4.2 below.

This analysis indicated that the readability of both the 1961 and 1963 editions of the Blue Version as measured by the Flesch and Dale-Chall procedures have mean readabilities in the 11th to 12th grade level range.

Belden and Lee[1] report in a study of the readability of texts and the reading abilities of science students that a series of five physics books ranged from a grade level readability score of 13.0 to 12.0 on the Dale-Chall Scale and a series of five chemistry textbooks scored from 12.1 to 9.8. In a study of the readability of biology texts[2] Belden and Lee, using the Dale-Chall readability Score, reported that the five textbooks studied were scored by them as having from 9.2 to 11.0 in grade level readability.

The relative placement of the mean readability grade level scores obtained in this study of the BSCS Blue Version materials and that obtained on biology texts by Belden and Lee are shown in Table 4.3. This table indicates that the Blue Version texts (1961 and 1963 editions) are at least as difficult as the most difficult book studied by Belden and Lee.

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[1] Bernard R. Belden and Wayne D. Lee, "Textbook Readability and Reading Ability of Science Students," The Science Teacher, XXIX, April 1962, pp. 20-21.

[2] ________ "Readability of Biology Textbooks and the Reading Ability of Biology Students," School Science and Mathematics, LXI, December 1961, pp. 689-693.

TABLE 4.1

Readability of the Blue Version of BSCS High School Biology Texts 1961 and 1963

FLESCH READING EASE

		SAMPLE 1 (S_1)		SAMPLE 2 (S_2)		SAMPLE 3 (S_3)	
		FREQUENCY		FREQUENCY		FREQUENCY	
SCORE	GRADE LEVEL	N	% of Total	N	% of Total	N	% of Total
70.0-79.0	7th	4	5.5	1	4.0	1	4.0
60.0-69.9	8th-9th	14	19.1	4	16.0	4	16.0
50.0-59.9	10th-12th	20	26.0	7	28.0	9	36.0
30.0-49.9	13th-16th	33	42.5	11	44.0	10	40.0
0.0-29.9	Coll. Grad.	5	6.9	2	8.0	1	4.0
TOTAL		76	100.0	25	100.0	25	100.0

Mean score ($\bar{x}$)	49.7=13th-16th g.	48.4=13th-16th g.	51.56=10th-12th g.
Standard deviation (S.D.)	12.2	12.3	11.1
$\bar{x}$ + 1 S.D.	61.9= 8th-9th g.	60.7= 8th-9th g.	62.7 = 8th-9th g.
$\bar{x}$ - 1 S.D.	37.5=13th-16th g.	36.1=13th-16th g.	39.6 =13th-16th g.

continued next page

TABLE 4.1--continued

DALE-CHALL READABILITY

		SAMPLE 1 (S_1)		SAMPLE 2 (S_2)		SAMPLE 3 (S_3)	
		FREQUENCY		FREQUENCY		FREQUENCY	
SCORE	GRADE LEVEL	N	% of Total	N	% of Total	N	% of Total
6.0-6.9	7th-8th	7	9.2	3	12.0	0	0.0
7.0-7.9	9th-10th	18	23.6	5	20.0	4	16.0
8.0-8.9	11th-12th	28	36.9	9	36.0	11	44.0
9.0-9.9	13th-15th	20	26.3	7	28.0	8	32.0
10.0-	Coll. Grad.	3	3.9	1	4.0	2	8.0
TOTAL		76	100.0	25	100.0	25	100.0

Mean score ($\bar{x}$)	8.4=11th-12th g.	8.2=11th-12th g.	8.7=11th-12th g.
Standard deviation (S.D.)	1.4	1.5	0.8
$\bar{x}$ + 1 S.D.	9.8=13th-16th g.	9.7=13th-15th g	9.5=13th-15th g.
$\bar{x}$ - 1 S.D.	7.0= 9th-10th g.	6.7= 7th-8th g.	7.9= 9th-10th g.

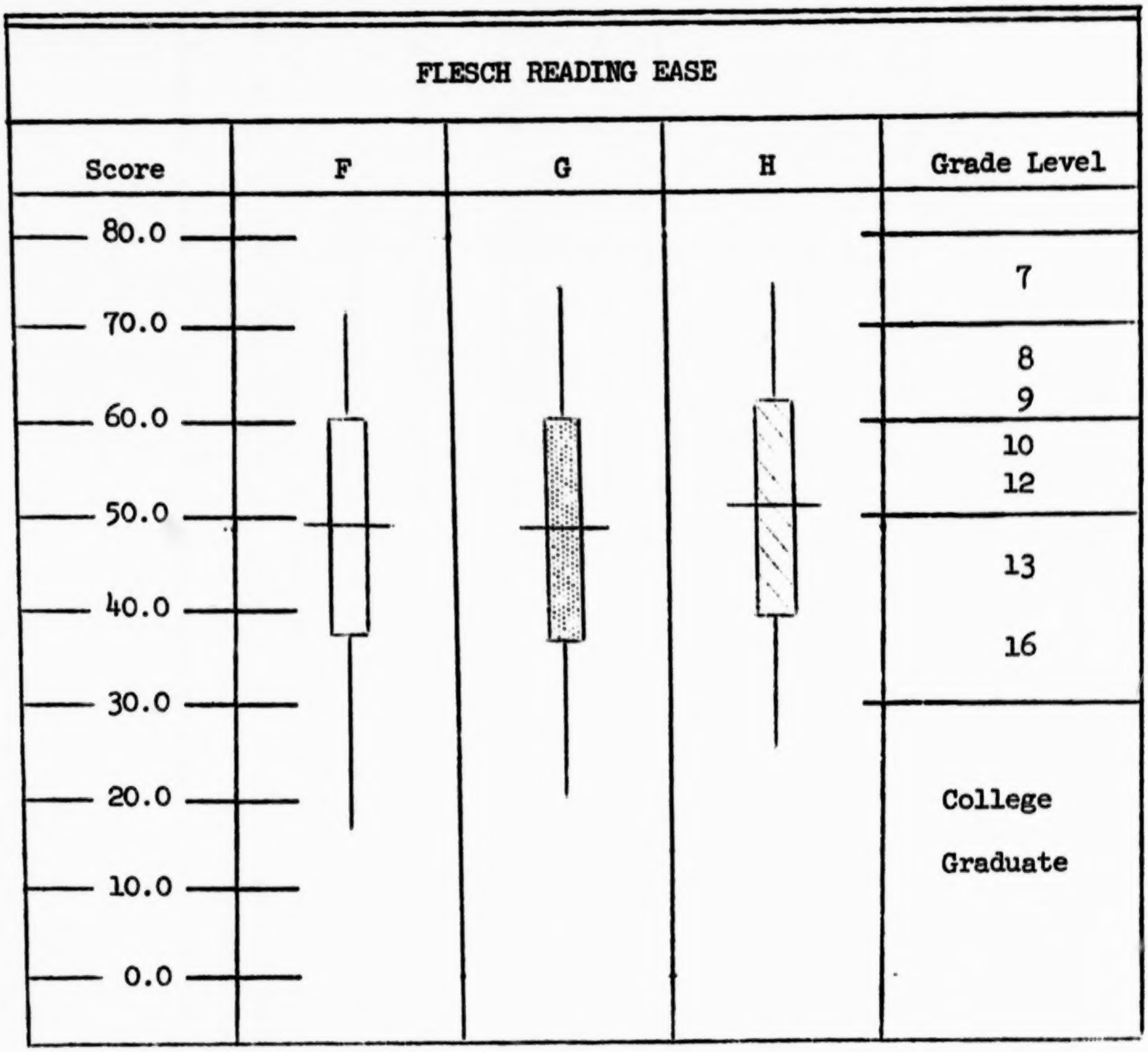
S_1 = 10% (76 selections) random sample of High School Biology Blue Version, revised edition, 1961.

S_2 = 3.3% (25 selections) sample selected by choosing every third selection from S_1.

S_3 = 3.3% (25 selections) sample selected by choosing samples to match each of the 25 selections from S_2 in content from Biological Sciences: Molecules to Man, BSCS Blue Version (Boston: Houghton Mifflin and Company, 1963).

TABLE 4.2

Readability of the Blue Version of BSCS *High School Biology* Texts 1961 and 1963



[F] = 10% (76 selections) random sample of *High School Biology* Blue Version (revised edition, 1961).

[G] = 3.3% (25 selections) sample selected by choosing every third selection from the 10% sample.

[H] = 3.3% (25 selections) sample selected by choosing samples to match each of the 25 selections above, these chosen from Biological Science: *Molecules to Man*, loc. cit.

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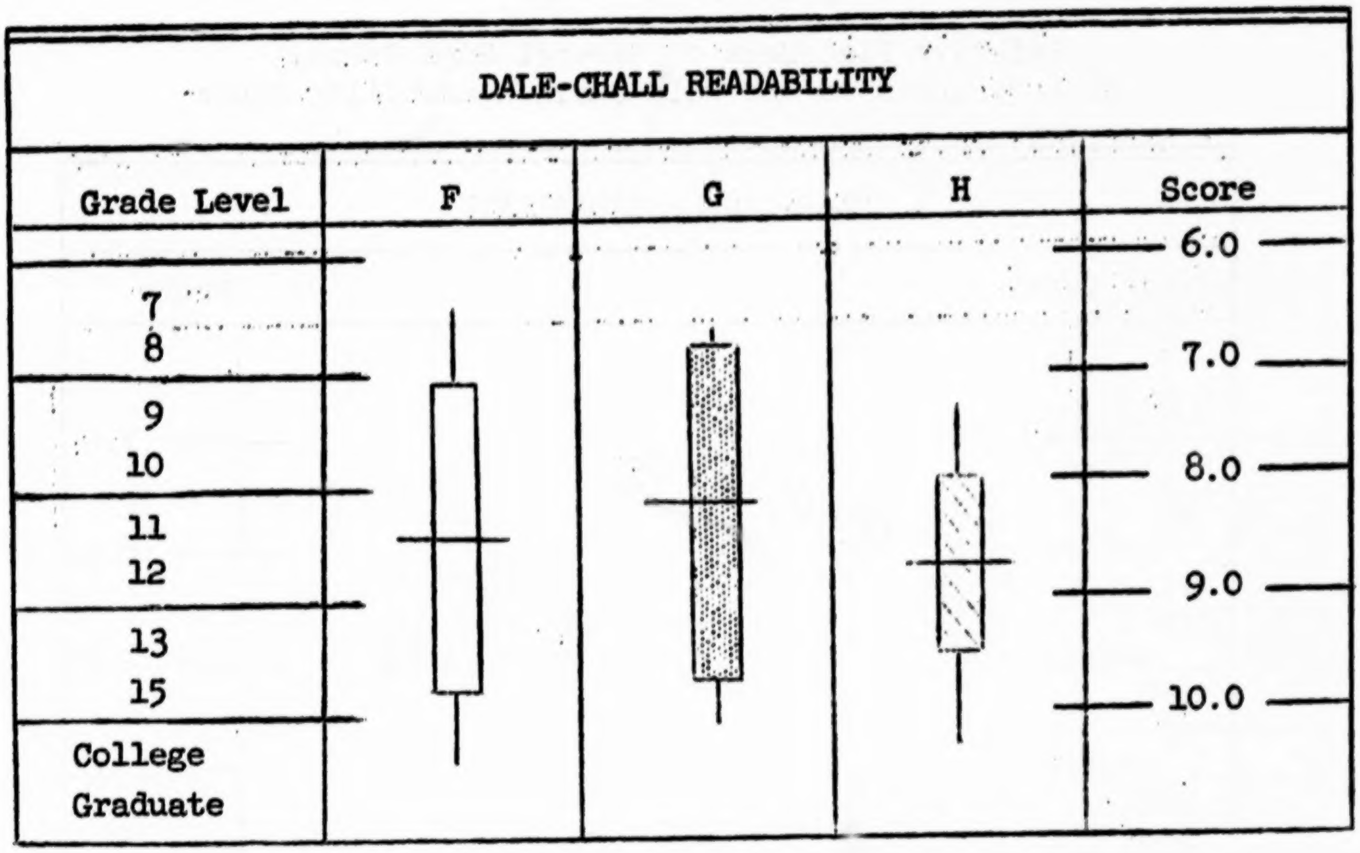
TABLE 4.2--continued



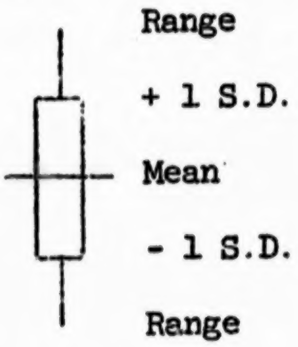
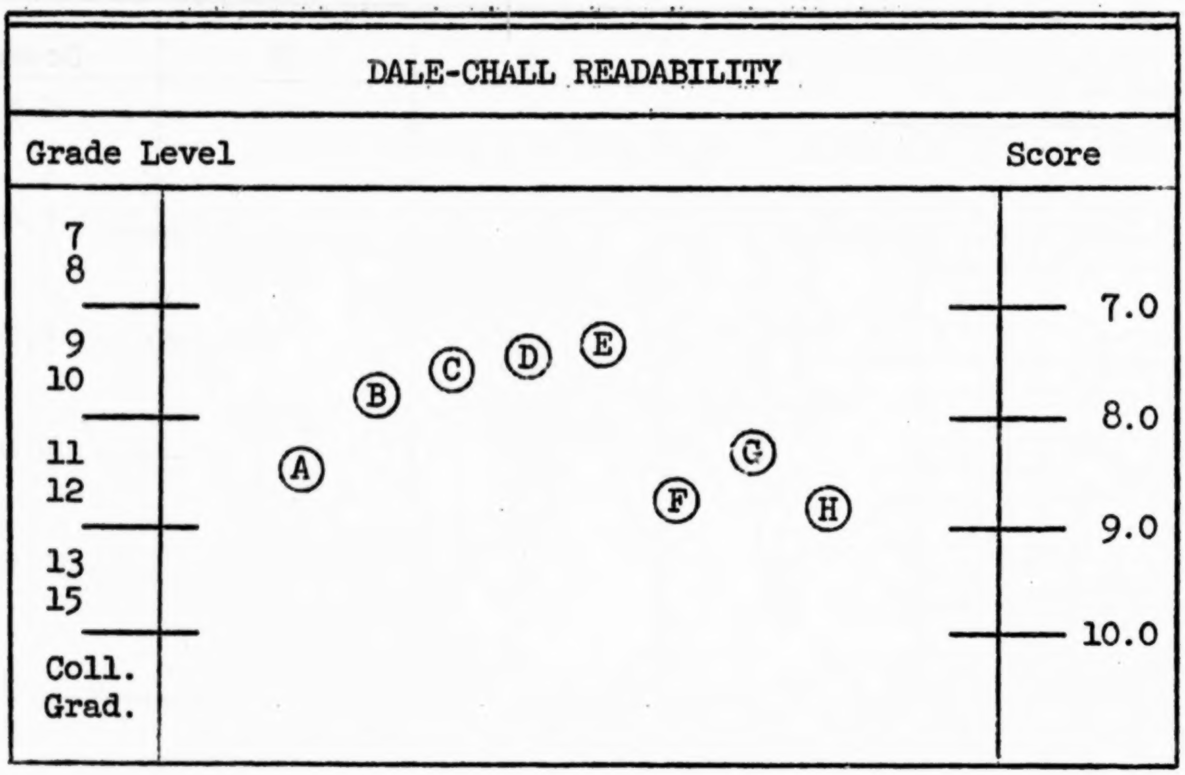


TABLE 4.3

Relative Placement of Several High School Biology Texts on the Dale-Chall Readability Score



A to E*

Baker, A. O., Mills, L. H., Tanczos, J. New Dynamic Biology. New York: Rand McNally and Company, 1959.

Dodge, Ruth A. Elements of Biology. Boston: Allyn and Bacon, 1959.

Kroeber, E., Wolff, W. H., Weaver, R. L. Biology. Boston: D. C. Heath, 1960.

Moon, T. J., Mann, P. B., Otto, J. H. Modern Biology. New York: Henry Holt and Company, 1951.

Smith, Ella T. Exploring Biology. New York: Harcourt Brace and Company, 1959.

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*These texts were listed in alphabetical order and cited as texts A to E but were not individually identified in Bernard R. Belden and Wayne D. Lee, "Readability of Biology Textbooks and the Reading Ability of Biology Students," loc. cit.

TABLE 4.3--continued

DALE-CHALL READABILITY

F High School Biology, Blue Version. Biological Sciences Curriculum Study, revised edition. Boulder, Colorado: University of Colorado, 1961. (10% sample)

G High School Biology, Blue Version. Biological Sciences Curriculum Study, revised edition. Boulder, Colorado: University of Colorado, 1961. (3.3% sample)

H Biological Science: Molecules to Man. Biological Sciences Curriculum Study. Boston: Houghton Mifflin Company, 1963. (3.3% sample)

One of the aspects not assessed by the readability formulas which were used in this study was the rate at which scientific terms were introduced. As a part of process of assessment of the text readability of the 1961 edition, those words which did not appear on Dale's list of 760 words were recorded from each 100-word selection studied. The listed words were categorized into scientific terms and non-scientific terms. The basis of categorization was with regard to both obviously identifiable scientific terms such as "actomyosin" to words which, in the judgment of the writer, were being given special scientific meaning such as "assume" and "assumption."

The frequency of scientific terms per 100 words sampled was 4.2. This calculation does not include the number of times each particular word was repeated on a given page or throughout the text--each word is counted only once. Thus it may be concluded that each of the terms appearing in the frequency count is a new scientific term. This conclusion is based in turn upon the assumption that the prior science background of students had not contributed to their acquisition of scientific meanings for these scientific terms. With this assumption in mind, a rough calculation can be made of the number of new scientific terms introduced in the 1961 edition of the text if the proportion reflected in this sample is maintained throughout the text. To make the estimate conservative, we will assume 700 pages of continuous text, leaving out those pages which were largely blank, those which contained questions, drawings, etc. A rough calculation indicates that full pages have more than 300 words but that many drawings are interspersed; therefore, the writer assumed an average of 250 words per page. This rough calculation would produce approximately 175,000 words in the text. At the 4 percent rate, this would indicate an introduction of approximately 7,000 scientific terms in the course of the year. The intention of the BSCS writers was to reduce the number of terms introduced into the science course; for, as John Moore observed:

> We discussed the importance of restricting our vocabulary to necessary terms (someone presented the startling information that high school students are confronted with more new words in current biology courses than in their foreign language courses) and we agreed on the necessity of making biology a truly intellectual experience and not merely a catalogue of facts pertaining to plants and animals.[1]

It would seem that this goal was not wholly achieved. Even assuming a 50 percent error in estimation which would reduce the number of new scientific terms to 3,500 words, Hurd reports that Pressey, in 1924, found an average of 1,393 technical terms in high school biology texts,

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[1] John A. Moore, "The Committee on the Content of Curriculum," BSCS Newsletter 2, the Biological Sciences Curriculum Study, University of Colorado, January 1960, p. 5. The only basis for this statement which the writer has found is cited in Jeanne S. Chall, Readability An Appraisal of Research and Application (Columbus, Ohio: The Ohio State University, 1958), based upon research by Luella Cole, 1924, and S. R. Powers, 1925.

1,504 in general science texts, 1,297 in chemistry texts, and 1,040 in physics texts.[1]

Thoughts on the "'Is' of Identity."[2]

Let us first look at a problem which was evidenced in the 1961 edition of the Blue Version and is later also seen in Molecules to Man--the use of the "'is' of identity" to link different levels of abstraction and thus convey to the reader an identity as between the terms or ideas on each side of the word "is."

For example, on page 3 of the paperbound edition of 1961 there appear the following uses of "is":

> . . . one of the main functions of this book is to give you what we think is the essential nature of science and the scientist.[3]
>
> \- -
>
> First of all an hypothesis is any tentative solution to a problem. The verification of the hypothesis is accomplished if some means can be found to test whatever the hypothesis maintains to be "true."

On page 1 of Molecules to Man appears the following statement: "The variety of living things is a fact, obvious to everyone." What would be the notion of the nature of "fact" for the young student of science after this reading? A modification occurs on page 4 as the student is given the definition for "fact" as follows: "(A fact may be defined as any observation that can be confirmed by many people.)" And on page 3 the student reads: ". . . science is the interaction of facts and ideas." The meaning of "hypothesis" is also extended on page 4 as follows:

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[1] Paul DeH. Hurd, Biological Education in American Secondary Schools, 1890-1960. Biological Sciences Curriculum Study Bulletin No. 1 (Washington, D.C.: American Institute of Biological Sciences, 1961), p. 201.

[2] See Irving J. Lee, Language Habits in Human Affairs (New York: Harper and Brothers, 1941), pp. 229-243.

[3] The italicizing of "is" in the quotation is that of the present writer.

> The creative part of his work, however, comes when he makes a tentative solution to the problem. This tentative solution, called a hypothesis . . . , must not only account for all the known facts, but should also predict that certain other events have happened. Explanation and prediction, then, are the two main functions of a hypothesis.

Are the foregoing statements helpful reminders of the nature of science for the high school age student--or the student of any age? Are the erroneous leads, with later modifications, helpful to the beginning student? Is the analogy of the "detective," in the context of which these excerpts are found, of assistance or a hindrance? The role of theory in guiding observation is not emphasized. The approach seems to be one of inductive analysis rather than one of a carefully stated pattern of deduction and induction--it is as though the scientist works without a history of other workers; as though he has no "giants" upon whose shoulders he can stand. The point of the well prepared mind is touched upon in the quote from Einstein on page 4 of Molecules to Man and returned to in paragraph three of column two on this same page; but the writer is sure that the point would elude the 10th grade general student in biology.

These brief comments have been included in this commentary on the readability of biology materials since it points to an aspect of analysis which, in the judgment of the writer, will need further investigation as refinements are made in the appropriateness of writing which seeks to convey the nature of scientific knowledge to the younger high school student.

Magazine Reading of Students

As a further probe into aspects of the readability of the text materials for the student population, the answers of the students to question 9 on the "Biology Questionaire"[1]--"What magazines do you regularly read?"--were totaled separately for boys and girls for each teacher. There were 742 questionaires with 89 students indicating that they regularly read no magazines. The remaining 653 students accumulated a total of 1332 responses by providing various magazine titles.

In evaluating the responses of the students to magazine reading, the ranking of titles for their "intelligence challenge" developed by Gray and Rogers in Maturity in Reading was utilized.[2] Since some titles were not on the Gray and Rogers list, the criteria for "intellectual challenge"[3] was informally applied to these titles and a placement in the five point scale determined.

The findings from this preliminary probe are summarized in Tables 4.4 through 4.8. These Tables present information which indicates:

1. Boys in the study read somewhat more total magazines than the girls.
2. Boys in the study group read more heavily than the girls in those magazines which might be termed as closely allied to science related interests--National Geographic, Scientific American, Popular Science, and hobby magazines which seem related to science interests at the high school age level.

Gray and Rogers observed that reading interest seemed more related

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[1] See Appendix B.

[2] William S. Gray and Bernice Rogers, Maturity in Reading (Chicago: University of Chicago Press, 1956).

[3] Ibid., p. 98.

TABLE 4.4

Rank Order of Density Response to Magazine Reading of 368 Boys and 374 Girls

	TOTAL MAGAZINES READ			
Rank Order	Teacher	No. Students	Sex	Density Ratio[1]
1	G	60	G	2.4
2	G	52	B	2.3
3	D	48	B	2.2
4	B	71	B	2.0
	D	56	G	2.0
	E	40	B	2.0
5	C	53	B	1.9
	C	39	G	1.9
	B	88	G	1.9
6	E	26	G	1.7
7	A	20	B	1.5
	A	37	G	1.5
8	F	84	B	1.4
9	F	68	G	1.3

SCIENCE INTEREST MAGAZINES[2]			
Rank Order	Teacher	Sex	Density Ratio[1]
1	D	B	0.48
2	G	B	.40
3	C	B	.30
4	B	B	.28
5	A	B	.25
6	F	B	.18
7	D	G	.16
	B	G	.16
8	C	G	.10
	E	B	.10
	G	G	.10
9	A	G	.03
10	F	G	.01
11	E	G	.00

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[1] Density ratio is calculated by dividing the number of responses by the total number of students of a given sex filling out the questionaire.

[2] National Geographic, Scientific American, Popular Science, Science Digest, Natural History, Sky and Telescope, U. S. Camera, etc.

TABLE 4.5

Rank Order of Density Response to Magazine Reading of 368 Boys and 374 Girls

TOTAL MAGAZINES READ				
Rank Order	Teacher	No. Students	Sex	Density Ratio[1]
1	G	60	G	2.4
2	G	52	B	2.3
3	D	48	B	2.2
4	B	71	B	2.0
	D	56	G	2.0
	E	40	B	2.0
5	C	53	B	1.9
	C	39	G	1.9
	B	88	G	1.9
6	E	26	G	1.7
7	A	20	B	1.5
	A	37	G	1.5
8	F	84	B	1.4
9	F	68	G	1.3

GENERAL NEWS, TOPICAL, and TOPICAL-PICTORIAL MAGAZINES[2]			
Rank Order	Teacher	Sex	Density Ratio[1]
1	G	G	1.11
2	D	B	1.00
3	B	B	0.95
4	C	G	.90
	G	B	.90
5	C	B	.88
6	D	G	.84
7	B	G	.82
8	E	G	.69
9	E	B	.65
10	F	B	.62
11	A	G	.59
12	A	B	.55
13	F	G	.51

[1] Density ratio is calculated by dividing the number of responses by the total number of students of a given sex filling out the questionaire.

[2] _Time_, _Newsweek_, _U. S. News and World Report_, _Life_, _Look_, _Reader's Digest_, _Saturday Evening Post_, _Saturday Review_, _Harpers_, _Atlantic_, _American Mercury_, _New Yorker_, etc.

TABLE 4.6

Density Differences Between Boys and Girls on Science Related Magazines

Rank Order	Teacher	Density Ratio By Sex[1]	Boy and Girl Differences
1	D	G .16 B .48	B + .32
2	G	G .10 B .40	B + .30
3	A	G .03 B .25	B + .22
4	C	G .10 B .30	B + .20
5	F	G .01 B .18	B + .17
6	B	G .16 B .28	B + .12
7	E	G .00 B .10	B + .10

[1] Data from Table 4.4.

TABLE 4.7

Density Differences Between Boys and Girls on General News and Pictorial Magazines

Rank Order	Teacher	Density Ratio By Sex[1]	Boy and Girl Differences
1	G	G 1.11	G + .21
		B .90	
2	D	G .84	B + .16
		B 1.00	
3	B	G .82	B + .13
		B .95	
4	F	G .51	B + .11
		B .62	
5	E	G .69	G + .04
		B .65	
	A	G .59	G + .04
		B .55	
6	C	G .90	G + .02
		B .88	

[1] Data from Table 4.5.

to the extent of their respondents' worlds than to their intelligence.[1] In viewing the magazine reading reported above and the norms of the VR + NA on the DAT of the students in this study, the writer questions whether the magazine reading of girls may not be indicative of the narrowing of the girls' environment--a narrowing which may retard the development of basic aptitudes. Do the magazine reading differentials as indicated in Tables 4.4 through 4.8 reflect the extent of the worlds of the growing adolescent girls and their perceptions of their need for reading as a part of preparation for later life tasks? May not the DAT raw score more accurately predict continuing interest and productivity in science while the percentile score may well reflect the ability to achieve the grades which are recognized as important for college entrance competition? As is often observed, girls receive higher grades than boys in high school, but it is also true that many fewer girls persist through the achievement of advanced degrees. These thoughts point to the need for future studies; for the questions which they raise cannot be answered within this report.

Using the conversion scores to grade placement devised by Flesch, and following the use made of these by Gray and Rogers,[2] the following grade placement of the magazines read by boys and girls was determined, shown in Table 4.8.

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[1] Gray and Rogers, op. cit. p. 98.

[2] Supra, p. 44.

TABLE 4.8

Reading Difficulty Levels of Magazines
Read by 742 Students

Flesch Score	Approximate Equivalent Grade Level of Flesch Score	Percentage of Magazines Read*	
		Girls	Boys
70-80 60-70	6th 7th and 8th	80.0%	45.5%
50-60	some high schoool	17.6	50.5
30-50	12th +	2.6	4.0
Total		100.2%	100.0%

*Three hundred seventy-four girls indicated 655 magazines read and 368 boys indicated 677 magazines read.

Little attention seems to be given in the literature to the relationships between readability studies and instruction, but the study of Killgallon[1] seems to be a basis for distinctions reported in the literature that the instructional level is assessed as being approximately one year below the "frustration level" and the "basal level" two years below "frustration." One rough criterion for the "instructional level" of material has been that only one word in twenty running words should need explanation and teaching.[2] If it may be assumed that the reading levels of the magazines reported above reflect the "basal" reading

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[1] P. A. Killgallon, Study of Relationships Among Certain Pupil Adjustments in Language Situations. Doctoral Dissertation. (State College, Pennsylvania: The Pennsylvania State College, 1942.) Cited in Emmett Bett, Foundations of Reading Instruction (New York: American Book Company, 1957), pp. 445-454.

[2] Bett, op. cit. p. 445.

level, and with the pattern of text usage discussed above, the instructional level for the students in this study would be placed at about the 9th to 10th grade for the girls and, perhaps, a year higher for the boys. Comparing these data with the readability studies presented in the first section of this chapter, there appears to be substantiation for the reported difficulties which teachers found with a large segment of their students in the students' ability to read and understand the text.

Comments and Conclusions

From this preliminary work in assessing the readability of the Blue Version texts of the BSCS, the investigator would like to bring into focus certain concerns. First, it is important to remember that each of the readability formulas is based upon a different configuration of language elements, with different methods underlying the criterion of grade placement which is assigned. Thus, the formulas provide a relative positioning of materials based upon the given language elements, but the grade placement derived is not absolute. Second, recent research of Noam Chomsky[1] at the theoretical level and of Walter Loban[2] at the applied level point to the importance of other language elements as being of perhaps more central importance in defining the difficulty of reading materials. Of particular interest in this regard is the degree and complexity of patterns of subordination.[1] Third, the rate at which abstractions are introduced without adequate development of their extensive meaning needs to be investigated by methods applicable to the sciences. Fourth, concern needs to be given to the population for whom the materials were developed including the characteristics of this population in terms of general analytical ability and reading ability, and to further exploration of the utility of using recreational reading data as a dimension of analysis in assessing instructional materials designed for outside reading on the part of students.

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[1] Noam Chomsky, Syntactic Structure ('S-Gravenhage, The Hague, The Netherlands: Mouton and Co., 1957).

[2] Walter Loban, Language Ability in the Middle Grades of the Elementary School, Final Report to the United States Office of Education, Department of Health, Education and Welfare, March 1, 1961, OE Contract Number SAE 7287.

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[1] Loc. cit.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Levels of Student Understanding

This study developed a series of instructional tests patterned to assess selected aspects of specific goals of instruction developed during a year course in high school biology. The report has been purposefully descriptive in order to provide as complete information as practicable regarding the way in which the instructional tests were developed and the relationships of specific questions to the objectives of instruction. The analysis of each test has been presented in such a way as to provide interested workers with raw data from which the interpretations of this investigator may be tested.

Before the problems presented in Chapter I can be discussed, the reliability of the instructional tests must be considered. Reliability coefficients were calculated by Gulliksen's method.[1] These coefficients are presented in Table 5.1.

Gulliksen states that achievement examinations are generally regarded as self-validating.[2] This position is stated also by Guilford when he writes: "to know that accuracy of measurement in terms of reliability, then, is of first importance; for assuming selections of

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[1] Gulliksen, op. cit., p. 224.

[2] Supra, p. 16.

TABLE 5.1

Reliability Coefficients of Eight Instructional Tests

Test Number	Reliability r_{tt}	Standard Error of Estimate*
41	0.53	1.4
42	.68	1.5
43	.66	2.0
44	.80	2.6
46	.68	2.3
48	.90	3.4
49	.82	2.8
55	0.86	3.0

*Calculated by $S_e = S.D. \sqrt{1 - r_{tt}}$

relevant material, accuracy is the only question to be raised."[1] The writer has sought to utilize standard statistical procedures in determining reliability of the instructional tests developed as a part of this study but has come to question the usefulness of this procedure. It is instructive to recall that computations of reliability coefficients are influenced by test length. Such influence is illustrated in Figure 5.1 which shows the computed test reliabilities as a function of test length.

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[1] J. P. Guilford, Psychometric Methods (New York: McGraw-Hill Book Co., Inc., 1954), p. 388.

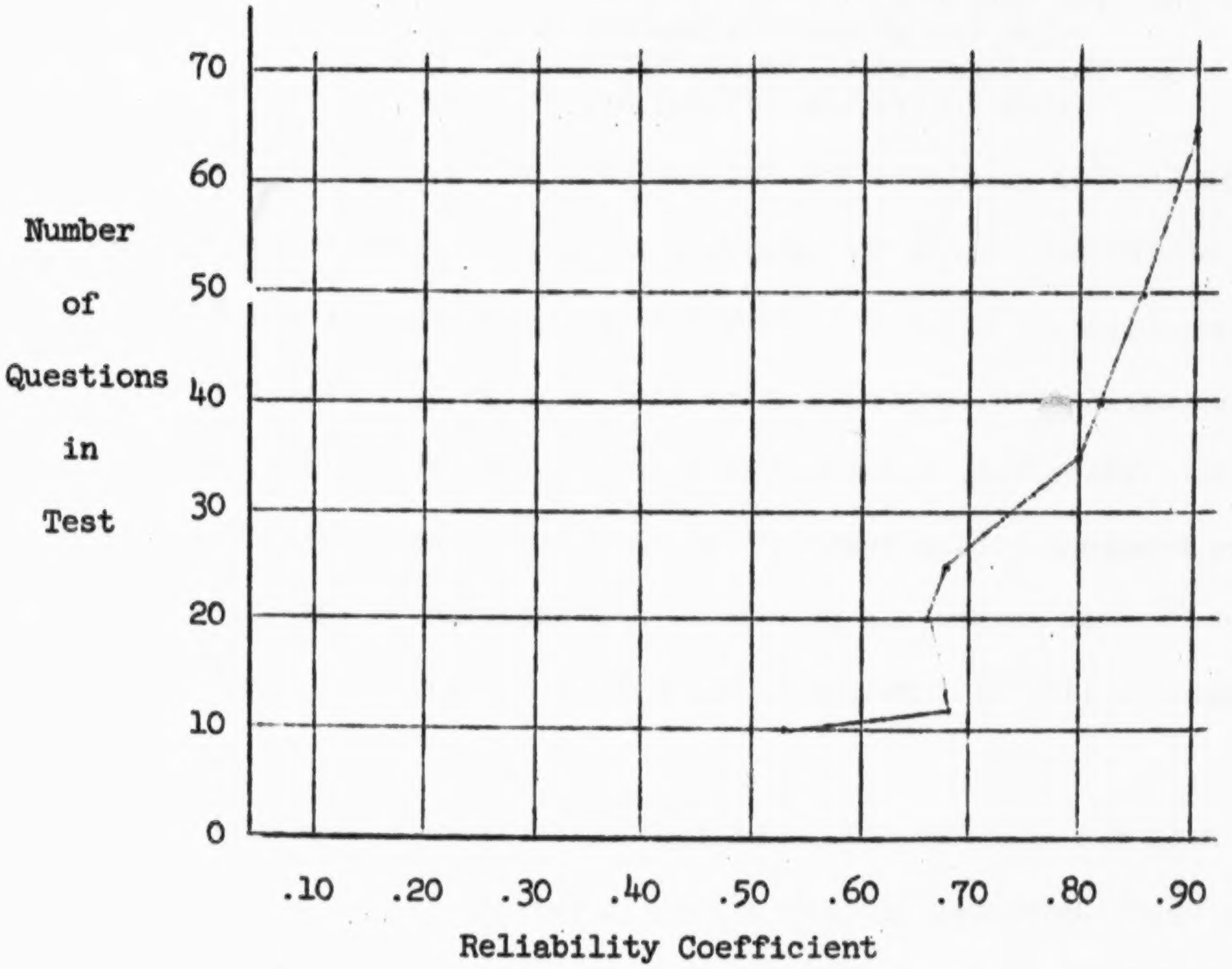

Fig. 5.1.--Test Reliability Coefficients (See Table 5.1) plotted in relation to test length, for the eight instructional tests in this study.

Although Gulliksen has shown that his alternative to the Kuder-Richardson formula 20 avoids the assumption of equal question difficulty,[1] Gulliksen's assumption that the average co-variance of non-parallel items is equal to the average co-variance of parallel items remains unverified in this study. Guilford, in commenting on internal consistency reliability operations, states that these reliability coefficients are greatest when

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[1] Gulliksen, op. cit. p. 224.

1. The item inter-correlations are greatest.
2. The variance of items is greatest. This is when the proportion passing an item is .50.
3. The items are of equal difficulty. Then the item inter-correlations are at a maximum.[1]

The writer questions the desirability of constructing instructional achievement tests to improve a reliability coefficient in view of these criteria. From the viewpoint of instruction it would seem more appropriate to construct items with a range of difficulties. A very high reliability index may be a better indication that the test is more homogenous than desired than that its retest reliability is "better."[2] The writer can only raise the question at this time as to the applicability of internal consistency reliability of instructional tests.

From the calculated reliability coefficients of the eight instructional tests developed in this study, it may seem that from a statistical standpoint the tests lack sufficient reliability for determining levels of student understanding. The writer considers the internal-consistency reliability coefficient used as of limited value in assessing the dependability of the tests for the purposes of this investigation. As Guilford indicates, to make a single test both highly valid and highly reliable internally is to work at cross purposes; for

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[1] J. P. Guilford, Fundamental Statistics in Psychology and Education, 3rd Edition (New York: McGraw-Hill Book Co., Inc., 1956), p. 456.

[2] These same concerns are explored more thoroughly by Raymond B. Cattell, "Beyond Validity and Reliability: Some Further Concepts and Coefficients for Evaluating Tests," The Journal of Experimental Education, Vol. 33, No. 2 (Winter 1964), pp. 133-143.

> maximum reliability requires high intercorrelation among items; maximum validity requires low intercorrelations. Maximal reliability requires items of equal difficulty; maximal validity requires items of differing in difficulty.[1]

In discussing the compromising of aims in developing valid, reliable tests, Guilford indicates for tests with well-constructed items, reliabilities will not often be above .90 and that item-test correlations will range between .30 and .80, with " . . . probably better reasons for going below these limits than above them in constructing items."[2] In the writer's judgment the tests meet item-test correlations and are considered dependable for discussing those student understandings assessed.

The major problem raised in this study was that of assessing levels of understanding of a group of students using the BSCS Blue Version materials. The detailed discussion of the various levels of understanding achieved by the Test Groups, the Cans, and the Cannots has been presented in Chapter 3. A summary of the achievement of the Test Groups, the Cans, and the Cannots for each of the eight instruments is presented in Figure 5.2. It will be noted that whereas the mean achievement for the Cans on each of the tests ranged from a high of 90 percent correct to a low of 72 percent correct, that of the Cannots ranged from a high of 39 percent to a low of 31 percent correct. From the data presented it may be concluded that levels of understandings achieved by the Cans differed both quantitatively and qualitatively from the Cannots. The qualitative differences are

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[1] _Ibid_. p. 471.

[2] _Loc_. _cit_.

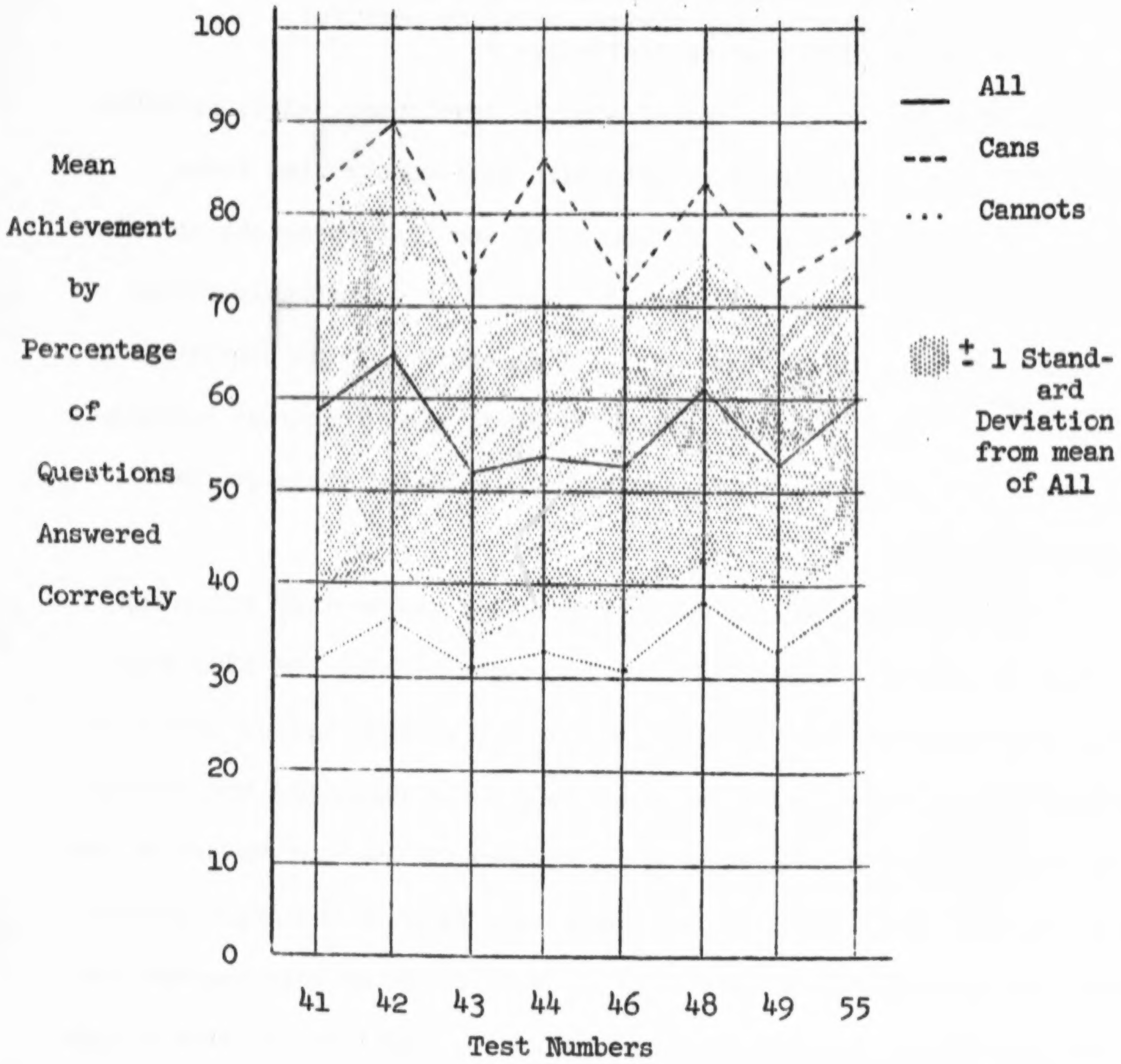

Fig. 5.2.--Mean Achievement of Test Group, Cans, and Cannots for each of the eight instructional tests.

based upon the distractor selection analysis presented in Chapter 3. The Test Groups had a range of achievement on the eight instructional tests from a high of 65 percent to a low of 52 percent. The mean achievement of the Cans is above one standard deviation from the mean of the Test Group and that of the Cannots is below one standard deviation from the mean of the Test Group. The form of the data did not permit the use of analysis of covariance to determine significance of differences between groups when adjusted for aptitude differences. This calculation might be of some interest but is not considered essential for the purposes of this investigation; for the writer remains unconvinced that the statistical adjustment of aptitude test scores can "equate" student groups for interpreting achievement.[1] The differential achievement as measured by these eight instructional tests raises the question of whether or not this achievement was satisfactory. A discussion of this problem involves judgments which have developed during this investigation but which extend beyond the data.

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[1] This statement is supported by the following statement from Carl Berecter, "How May Units of Measurement be Safely Ignored?" Journal of Educational Measurement, Vol. I, No. 1 (June 1964), p. 22: "It [analysis of covariance] is often used as an attempt to render groups comparable which could not otherwise validly be compared, because of systematic differences on related variables. This amounts to shifting whole groups to different plans in a multidimensional space; and it will require the strongest kinds of assumptions about score intervals, not only in the criterion variables but in the control variables as well."

Findings Regarding the Proposed Problems

Five problems were proposed at the outset of this study as being potentially fruitful for investigation. The data presented provide specific information for analyzing some of these problems, offer data bearing indirectly on others, and provide the investigator with a basis for the reformulation of some problems and the development of some new problems which might be investigated by future research or by further analysis of the data accumulated during this study. It has not been possible within the time limits established for this study to completely explore all of the proposed problems.

The methods of analysis used to determine levels of understandings of students as determined by the eight instructional tests did not provide data for the problem of the relationships of the most difficult questions on the instructional tests to the common characteristics which students answering these questions correctly might have. However, at a crude level, the relative achievements of Cans and Cannots and the positive discrimination of nearly all questions indicate the general correspondence of high DAT (VR + NA) to success on difficult items. Further analysis of student questionaire data and a more detailed study of item responses may yield further information on this problem.

A second proposed problem for study was to relate the performance of students on the objective instructional tests with laboratory performance testing in comparable areas and to compare the responses of students to these two means of assessment. One laboratory practical was given by some teachers in the middle of the year.[1] Due to a last minute change in school final examination schedules, only five of the nine teachers were able to administer the laboratory practical. As only four of the seven teachers whose achievement tests are presented in this study were able to administer the laboratory practical, the comparison of results of this test with achievement test questions was not possible within the limitations of presenting the data from seven teachers on the same tests.

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[1] See Table 2.1, p. 22.

The analysis of the eight selected tests which was presented in Chapter 3 of this study has shown how selected groups of students performed on various test items within the tests. This performance has been based upon a contrast between the students who did best on each of the tests (Cans) compared with those who did poorest (Cannots) and the Total Group taking the test. Each of the eight tests studied was developed from preliminary instructional objectives which have been identified in the analysis of each test. It is now appropriate to reexamine selected questions in terms of the course objectives as defined by the Biological Sciences Curriculum Study.

The BSCS planned the text and laboratory materials of the Blue Version, as well as of the other versions, so as to develop nine major themes and objectives. Two of these themes provide the basic structure of the text and provide the context through which the more specific content themes are conveyed. These are:

1. Science as enquiry--the processes of science, including the uncertainty and incompleteness of the conclusions of science.
2. The history of biological conceptions.

Two themes are intermediate between these structural themes and the more specific content.

3. Complementarity of structure and function.
4. Regulation and homeostasis: preservation of life in the face of change.

The five remaining themes concern the "content carriers" of the text and laboratory materials. They are the media through which an understanding of the basic and intermediate themes of the structure of the text are to be achieved.

5. Evolution--including the history of living things, the processes of change, and evolution as a cause or consequence of change.
6. Diversity of type and unity of pattern.
7. Genetic continuity of life.
8. Complementarity of organism and environment.
9. The biological roots of behavior.[1]

These nine themes were selected on the basis of two major determining factors. (1) Those characteristics and conceptions which provide the most comprehensive and most reliable knowledge of living things as they are known to modern biology, and (2) the needs of our nation and our fellow citizens.[2] It will not be possible to assess the relationships of all of the questions given to the nine major themes. However, in the analyses presented in Chapter 3 special attention was given to the theme "Science as Enquiry."

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[1] "Themes and Objectives of BSCS Materials," 1961 BSCS Teachers Handbook, Biological Sciences Curriculum Study, Boulder, Colorado: University of Colorado, 1961, pp. 37-50.

[2] Ibid. p. 37.

A total of 42 questions, of the 257 questions presented in this study, was categorized as assessing selected aspects of the nature of science. These questions are considered to be a sample by which the levels of student understandings of the theme "science as enquiry" may be assessed. Figure 5.3 shows the success of students on these questions by test number. The particular questions within each test may be secured from the analysis of the individual tests in Chapter 3.

The drop in achievement on Test 44 is partially attributable to the presence of a negative discriminating question.[1] The drop of roughly 20 percentage points on achievement from the Cans to the Test Group and from the Test Group to the Cannots is again evident.

Thus, with regard to the third problem proposed for this study--"How do selected students perform on test items concerned with general themes?"--we see that the performance for the themes "science as enquiry" parallels the general levels of performance on the tests as units. With an analysis of only eight of a possible sixteen tests used during the year this performance must be regarded as tentative. Since certain themes are assessed by tests excluded from this study further analysis of thematic understanding will not be a part of this report.

The fourth problem area proposed for this investigation was concerned with whether students of different academic aptitudes would achieve differentially if they were in contrasting types of classes. As with the problem related to class performance, the lack of data which could affirm the integrity of class groups made it impossible to pursue this particular problem.

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[1] See the discussion, p. 141.

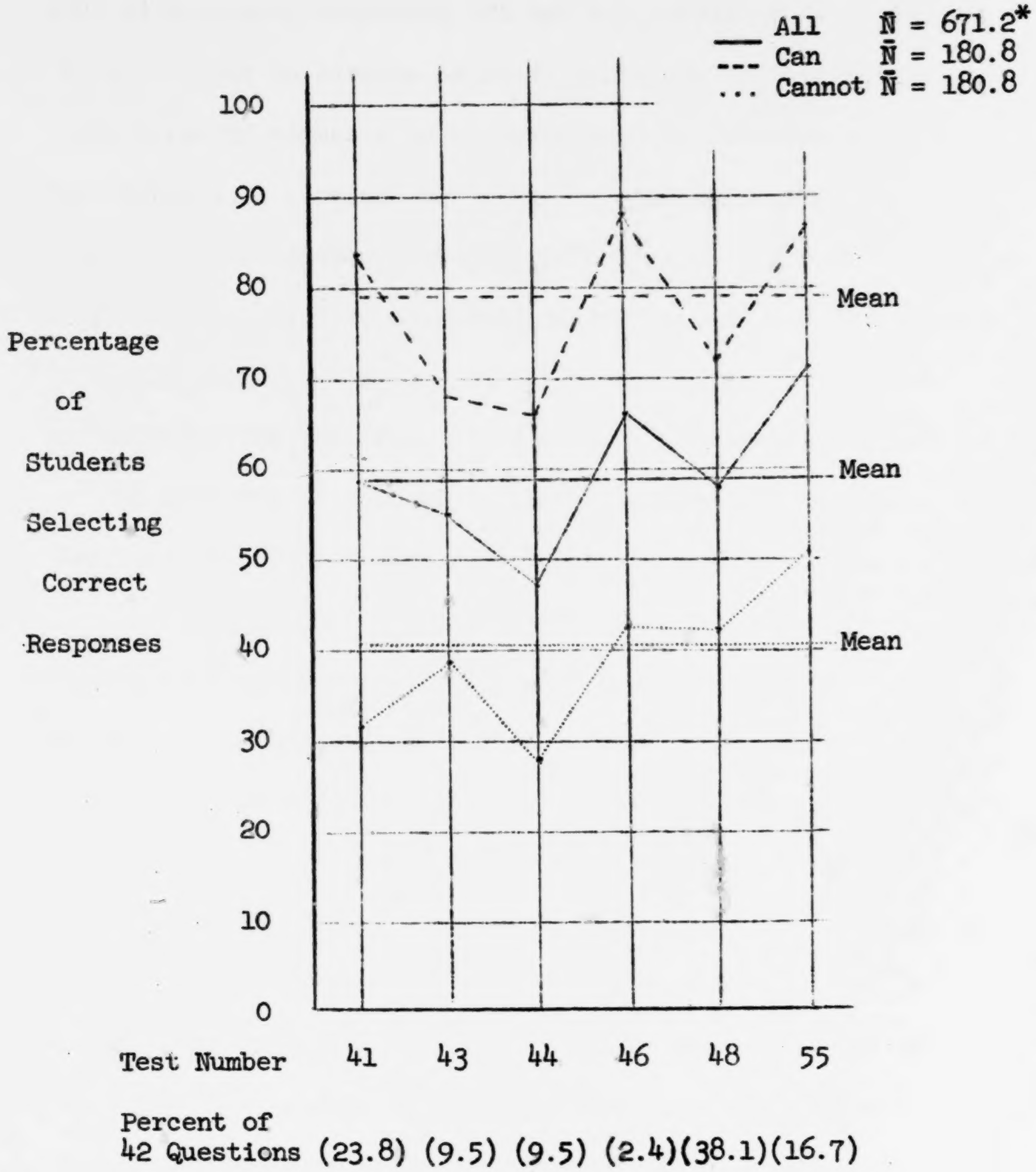

Fig. 5.3.--Achievement of Test Group, Cans, and Cannots on 42 questions categorized as assessing the "nature of science" from six tests given during the school year.

*Number of students was determined by averaging the total number of students in the Test Groups, Cans, and Cannots on each of six tests.

The last problem area, concerned with the relative discrimination of high, low, and middle groups with regard to tests which had different patterns of recall, application, and interpretation questions, may not at the present time be completed. Such consideration will be dependent particularly upon the processing of Test 51, Part 5, which was a completion type question series. Time did not permit the completion of this analysis for inclusion in this report. Insofar as the differential classification of questions categorized by the project director according to the Taxonomy may provide some insight into this problem, Test 42 and Test 43 had 83 and 60 percent respectively of questions categorized in the recall and recognition area, 1.00 according to the Taxonomy; and Test 49 and Test 55 had the lowest percentages, 25 and 26 percent respectively, categorized at this level. The relative fluctuations of the Cans and Cannots on each of these tests remained roughly parallel.

The Development of Instructional Tests

A major function of this investigation was to place the development of instructional tests within the context of instructional objectives at both high levels of generality, such as the themes and objectives developed by the Biological Sciences Curriculum Study, and at more intermediate or lower levels of generality which have been provided within the framework of analysis of each of the tests which has been reported. The development of analytical schemata for presenting what is involved in understanding a given idea seems to have been a fruitful approach for purposes of clarifying instructional objectives and for providing guidelines for the development of evaluative instruments.

The crucial questions of what are relevant content and processes to be taught and how can these be evaluated in order to assess achievement for general education in biology have been investigated but by no means solved by this study. The time available for instruction is an important dimension of the selection of what is to be taught from all that could be taught. If penetrating understanding of the nine major themes is to be achieved, then the hard questions of what constitutes understanding and at what levels would there be agreement that understanding has been achieved would seem to be fruitful questions for discussion on the part of teachers and science educators. One approach to operationally specifying levels of understanding would be to develop agreement on the degree of discrimination required to select "best" responses from among correct responses. Bruner's argument that any idea[1] ". . . can be taught effectively in some intellectually honest form to any child at any state stage of development"[2] needs to be conditioned by the necessity of achieving economy in education within the limited time available for instruction and with students capable within the instructional context of learning at various rates of speed. It becomes clear from this study that the institutional limitations which existed in the classrooms, the materials, and the evaluative instruments used in this study would not permit generalization to Bruner's viewpoint.

The *Taxonomy* has been shown to be a valuable instrument in extending the dimensions both of the development of objectives and for the development of test items which can be built into tests which are more than recall questions. Though the classification of questions into the *Taxonomy* seems to this writer to involve a large element of judgment on the part of the classifier, the utility of thinking in broader terms than recall and the assistance which the *Taxonomy* provides seem to be worth potential disagreements among evaluators as to the proper placement of a question. It must be understood, however, that when categorizing questions according to the *Taxonomy* which fall at the 2.00 level or above, the judgment must be made that the particular context expressed in this question has not been directly taught to the students.

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[1] Needless to say, the nature of what is meant by substantive qualities of "any idea" needs clarification. It has been a major burden of this study to "tie down" the meanings of many biological conceptions for the students engaged in biological study in the high school.

[2] Jerome S. Bruner, *The Process of Education* (Cambridge: Harvard University Press, 1960), p. 33.

If this is not true, then all questions categorized at 2.00 and above regress to knowledge at one of the three levels of recognition or recall. It is hoped that the development of instructional tests by the processes used in this investigation have illustrated the value of such processes in the clarification of instructional objectives and in the interrelationships of immediate objectives of instruction to the higher level, more pervasive, objectives of a year course in the biological sciences.

Instructional tests may also provide for a diagnosis of weaknesses in student understandings which are essential for future work in the particular course. Utilized in this way, the results of planned instructional tests may provide for a more critical basis for decisions as to needed re-teaching. Decisions to re-teach, perhaps through new content, in order to raise the level of understanding of the major objectives of the course, would seem to be a valuable outcome of well-developed instructional tests. Instructional evaluation may also be used to reflect back and assess the quality of instruction itself; for if the objectives proposed in this study are to be considered as essential objectives for general education in the biological sciences, and if the questions were to be agreed upon as effective questions for the assessment of the objectives, then the decision as to whether the achievement of students was adequate, especially the lower 27 percent of students in this study, must be carefully considered. As these tests were used, for example, the teachers experienced problems of motivation of students when test results continually reflected an average achievement of classes at the 50-60 percent level. Students are much more used to 70 percent as satisfactory achievement, and the problems of maintaining interest and motivation when achievement drops to the level which is exhibited by the core tests presented here is an important factor in the process of instruction.

It should also be noted that the teachers called attention to the slight differences in the wording of questions which were in effect different from the way in which they, in discussions and presentations, had dealt with a particular problem. In many instances, according to their judgment, this difference was sufficient to lower the student responses to such questions. There was a general feeling that questions developed by an external source brought lower general achievement than they, as teachers working with these students, felt was the understanding of the students. This problem has lead the investigator to question whether the goal of instruction in a particular school by a particular teacher is for knowledge which may be communicated only within the context of the language of the teacher and the student in that particular situation, or whether the goal is for generalized knowledge which can be approached through different language chains and word usages so that a student in "School A" may be able to discuss in depth problems in biology with a student in "School B." This consideration raises rather serious questions for those instructional situations in which the students are never evaluated by instruments other than those prepared by the teacher in charge of their instruction.

This investigator considers instructional tests as operationally defined by the instruments presented in this study as having different objectives and goals from standardized achievement tests. Instructional tests as here defined are test instruments which are sepcifically designed to measure the defined objectives of instruction in a particular situation for a particular group of students; as such, the universe of knowledge within a field is drawn upon for evaluative purposes in terms only of those aspects of the subject field which are the sources of instructional objectives for the given maturity levels found in the particular student population.

Recommendations for Further Study

Several suggestions for further study have been made earlier in this paper.[1] The writer considers the detailed documentation and analysis of the teaching-learning situation as an essential accompaniment of evaluating student understandings as the most important field for further research. Such documentation and analysis, coupled with different kinds of tested evaluative instruments, e.g., objective tests, essay tests, laboratory practical tests, etc., may provide for the formulation of more precise problems for investigation.

The provision for documenting the students entering and leaving each class as a part of research designed to assess classroom learning would seem to be essential. This recommendation has developed as the writer has observed apparent differences among class groups as data for this study was compiled and has felt that the compiling of such data may obscure important differences within the various classes of each teacher and among the groups of classes taught by different teachers. This observation leads to the suggestion that, at the current level of knowledge of classroom learning, the class group may be a more effective unit of study, even with limitations of student numbers, than data compiled from many classes and teachers.

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[1] *Supra*, pp. 9-15.

Analysis of achievement patterns of students of particular teachers in relation to the general ability of the students as assessed by the DAT or other criterion measures over several years is suggested as an added dimenstion to class group studies. Such analyses might provide for procedures and instructional tests which would eventually enable a teacher to compare his own effectiveness in development of student understandings with that of his colleagues and could become a device for planning for continuing education and self-improvement.

APPENDIX A

The materials in Appendix A were sent with the letter to the superintendents inviting participation of their districts in the project.

July 30, 1962

Dear :

Evaluating student understandings in the various subject fields continues as an unsolved problem in education. Last year a group of biology teachers with the assistance of the Division of Secondary Education of the Office of the Los Angeles County Superintendent of Schools worked together to develop a series of instructional tests and test questions as a step toward improving teacher-made tests.

In view of the importance of this work and the highly qualified leadership which we have in this field in Mr. James T. Robinson, our science consultant, we are planning to continue this project for 1962-63 with additional biology teachers from within Los Angeles County. Perhaps the purposes of the project for 1962-63 will help you in arriving at decisions as to whether you would wish your district to participate and as to the particular biology teacher you might wish to have represent your district. The general goals for 1962-63 are as follows:

1. To plan a common sequence of topics as a framework for instruction for the year. Such a framework will be developed from the sequence of topics in the 1961 edition of High School Biology, Blue Version, developed by the Biological Sciences Curriculum Study.

2. To plan the time when tests will be most helpful in assessing student understandings in biology.

3. To develop tests using as a basis a series of tests and test questions developed and tested during the 1961-62 school year by members of the Los Angeles County Center of the Biological Sciences Curriculum Study.

4. To gather data on student achievement in terms of goals of instruction in order to develop tested questions for assisting other teachers who may wish to use these questions.

A copy of the research design of the project and of the proposed calendar of meetings of the participating teachers along with the meeting agenda is enclosed. A sample copy of one quiz given early last year along with an analysis of the results of the quiz is enclosed for your information. Meetings will be held in the library of the Division of Secondary Education at 739 North Main Street, Los Angeles.

A return postcard is enclosed for your decision on representation in order that we may expedite notification of your representative for the September meeting.

Best wishes for a successful 1962-63 school year.

Sincerely,

John D. Lawrence
Director, Division of
Secondary Education

JDL:dw
Encl.

SCIENCE UNDERSTANDINGS OF BIOLOGY STUDENTS AS DETERMINED BY INSTRUCTIONAL TESTS: A PROJECT ON BROADENING THE BASIS OF EVALUATION IN HIGH SCHOOL BIOLOGY

An abstract of a proposed study sponsored by the Secondary Division of the Office of the Superintendent of the Los Angeles County Schools is attached to this paper. If a request for funds for the project now being considered by the U. S. Office of Education is approved ten biology teachers from Los Angeles County will be able to participate in this project during the 1962-63 school year.

The project will use the Blue Version of High School Biology, 1961 edition, prepared by the Biological Sciences Curriculum Study at the University of Colorado, Boulder, Colorado. In order to be eligible for participating in this project teachers will need to be using this text as a basis for instruction during the 1962-63 school year. Those teachers participating in the study will meet weekly or bimonthly with the project director to plan the time allocation of topics to be studied. The time allocation for each topic and the areas of emphasis within topics developed in these planning meetings will be used on a framework for evaluating student understandings of instruction. Teachers will be reimbursed for mileage to and from the meetings if the U. S. Office grant is approved.

The project director will prepare, mimeograph, and provide copies of instructional tests for use by the teachers in the project. These tests will be developed from test questions used in 1961-62 in Phase I of the project as described in the attached abstract. Weekly meetings will be utilized to evaluate, revise, and add new questions and testing devices appropriate for the framework of the course. Results of the tests will be supplied to the project staff for analysis.

Test booklets and answer sheets for the SCAT test will be provided by the project for administration by the participating teachers early in the school year. Districts will be asked to provide for access to their regularly administered standardized test data. Data of interest to the project will be intelligence or other ability test data and achievement test data in reading, if available. In order to provide information on the group of students in the project the district standardized test data will need to include access to other students taking the same course and to the total tenth grade population in the school.

Analysis of the results of the project will be used to develop a folio of test questions for use by high school biology teachers. Several grids which will enable teachers to quickly prepare a test which will enable them to assess student understandings in areas beyond factual recall will be provided. Publication of the results will be carried out by the Los Angeles County Schools Office.

If your school district is interested in discussing the project in greater detail please call Jim Robinson at Madison 8-9211, Extension 63332.

Abstract

This study proposes to develop and test classroom evaluative instruments for assessing the science understandings of tenth grade biology students. The instruments are being developed and tested in the school year 1961-62 with approximately 700 students who are using the Blue Version of High School Biology developed by the Biological Sciences Curriculum Study (BSCS)--University of Colorado, Boulder, Colorado. The study is designed to develop classroom test questions and tests on the basis of grid procedures. This analysis seeks to determine the levels of understandings which students of differing characteristics develop on a series of questions. These questions attempt to measure recall, interpretation, comprehension, analysis, etc. In addition the series of questions attempts to measure student understandings of the themes, goals, and concepts developed by the BSCS. From a study of these tests a folio of test questions for classroom teachers of high school biology will be developed. A series of grids will also be developed which will enable a teacher to pattern classroom tests for evaluation of understandings beyond factual recall.

Development of the test questions and tests involves discussions with the teachers of teaching objectives for each section of study in biology and of different measuring devices which might be used to determine the levels of student understanding of these objectives. Priorities from the most important to least important understandings are developed. Thus classes moving at different rates of speed have instruction designed to develop minimal understandings as well as more extensive understandings as time permits. Test questions are then written by grids devised to meet the objectives and levels of understanding desired.

Results of the tests developed and being used in the current (1961-62) school year will be studied to determine validity, reliability, and levels of understandings by Bloom's Taxonomy of Educational Objectives, etc. Correlations will be made to determine relationships between single and multiple characteristics of students and test questions and total test achievement.

Questions validated during 1961-62 will be used as a basis for developing new instruments which will be used during the 1962-63 school year. The results of the second year of study will be combined with the results of the first year to develop the final folio of questions and grids. Additional test procedures such as laboratory practical and essay tests will be compared with the results of objective tests as a part of the study.

Division of Secondary Education
Los Angeles County Schools Office
808 N. Spring Street
Los Angeles 12, California

Calendar of Meetings for the Biology Study Group

Semester I

September

5	Discuss project for 1962-63 Distribute evaluation of data from 1961-62 Discuss and develop planning calendar for the year Plan objectives for Test I Discuss SCAT testing and distribute materials
26	Distribute Test I Plan objectives for next section of study Examine and critique test questions for Test II

October

10	Return and critique Test I Develop grid for Test II Complete questions for Test II
24	Distribute Test II Plan objectives for Test III Develop grid for Test III Review schedule and adjust if necessary

November

7	Return and critique Test II Develop grid for Test III Examine and critique questions for Test III
14	Distribute Test III Plan objectives for Test IV Develop grid for Test IV Plan for Semester I examination
28	Return and critique Test III Discuss questions developed for Test IV Develop major ideas to have taught by end of Semester I Examine Semester I Final Examination from 1961-62

December

12 Distribute Test IV
Plan objectives for Test V
Develop grid for Test V
Review questions for Test V
Discuss and develop grid for Semester I Final

January

9 Return and critique Test IV
Distribute Test V
Discuss questions developed for Semester Final

16 Distribute Semester I Final
Review schedule for second semester
Examine data from Tests I, II, and III
Plan testing program for Semester II

Semester II

January

30 Return and critique Test V
Return and critique Semester I Final
Plan objectives for Test VI
Review questions for Test VI
Develop grid for Test VI

February

13 Distribute Test VI
Plan objectives for Test VII
Develop grid for Test VII
Review questions for Test VII

27 Return and critique Test VI
Discuss results of Test IV, and V
Complete Test VII
Plan objectives for Test VIII
Develop grid for Test VIII
Examine questions for Test VIII

March

13 Distribute Test VII
Review questions for Test VIII
Discuss results of Semester I Final

(March--continued)

27 Return and critique Test VII
Distribute Test VIII
Plan objectives for Test IX
Review schedule for remainder of Semester II

April

17 Return and critique Test VIII
Develop grid for Test IX
Review questions for Test IX
Discuss results of Test VI
Examine questions for Test X

May

1 Distribute Test IX
Plan objectives for Test X
Develop grid for Test X
Discuss questions for Test X

15 Return and critique Test IX
Distribute Test X
Discuss results of Test VII and VIII

22 Return and critique Test X
Discuss results of Test IX
Discuss outline and form of publication to be prepared for use by biology teachers

James T. Robinson
Consultant 7/20/62

Quiz: The Microscope
Name

____

1. a b c d e

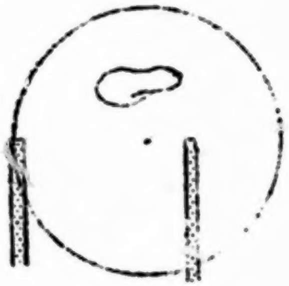
2. a b c d e

3. a b c d e

Quiz: The Microscope

Name ______________________ Period

The diagram below shows a section of a metric rule as seen through the objective of a compound microscope. Base your answers to questions 1-2 on this diagram.



1. a b c d e 1. The diameter of the field in the diagram is approximately

a. 1000 microns
b. 500 microns
c. 2000 microns
d. 1500 microns

2. a b c d e 2. The organism in the field of view is approximately

a. 100 microns in length
b. 500 microns in length
c. 900 microns in length
d. 1300 microns in length

3. a b c d e 3. The working distance in the compound microscope increases as the magnification.

a. increases
b. decreases
c. changes
d. remains the same

4. a b c d e

4. a b c d e

4. The resolving power of the microscope may best be said to be:

a. The extent to which you are magnifying an object.
b. The way in which your eye adjusts to the magnifying power of the microscope.
c. The degree to which the microscope will enable the eye to discriminate objects which it could not do unaided.
d. The distance which the lens is from the object.
e. The way in which you see an object through a microscope as though you are looking through a thin pane.

5. a b c d e

5. a b c d e

5. One of the following statements best explains why organisms under different powers seem to move at different speeds:

a. The area observed under high power is smaller and thus the organisms seem to cover the observed area more quickly.

b. The area observed under high power is larger than under low power and thus the organisms seem to cover the observed area more slowly.

c. The area observed under low power is smaller than under high power and the organisms seem to cover the area more quickly.

d. The area observed under low power is larger than under high power and the organisms seem to cover the area more quickly.

e. The area observed under low and high power is the same and the difference observed in the movement of the organisms is not related to the size of the area observed.

6. a b c d e

6. a b c d e

6. One of the following statements best explains why organisms under magnification move in and out of focus:

a. The experimenter makes slight shifts in the adjustment mechanism.
b. There is a failure to maintain a steady source of light for the microscope.
c. The organisms move in and out of different levels within the fluid.
d. The experimenter does not keep to careful and steady observation.
e. The experimenter did not prepare the slide with care.

7. a b c d e

7. a b c d e

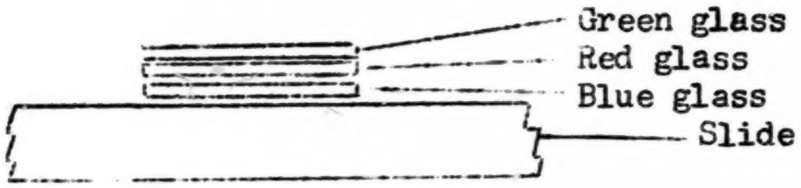
7. In using the microscope, which of the following would not be a true statement as presented in your laboratory manual:

a. Never use the coarse adjustment when the high power objective is being used.
b. Most microscopes allow you to change from one power to another without losing focus.
c. It is impossible to see all parts of an object clearly at one focus.
d. A thicker object may be brought into total focus more clearly at one focus than a thinner object.
e. Most microscopes are parfocal.
f. It is important to know how much you are magnifying an object.

8. a b c d e

8. a b c d e

8. If a slide were set up with a layer of blue glass, a layer of red glass, and then a layer of green glass as diagrammed below, a person using correct microscope technique would

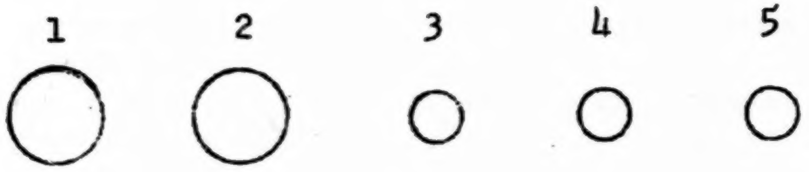


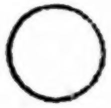
a. see the blue glass first
b. see all three glasses at once
c. see the red color first
d. see the green color first
e. see any of the color first which he wished to see

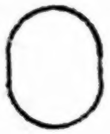
9. a b c d e

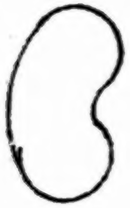
9. a b c d e

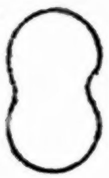
9. In viewing a thick object through the high power a student made a series of sketches of the object he observed at successive planes of focus. From his sketches, (nos. 1-5 below) what shape is the most accurate representation of a side view of the object?

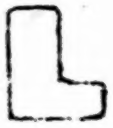


a.


b.


c.


d.


e.


10. a b c d e

10. a b c d e

10. When using the lower power objective

a. a greater area of the slide can be viewed than with a higher powered objective.
b. there is a greater ability to see smaller objects than with a higher powered objective.
c. the area of the slide in view remains the same, but the depth in view is decreased as compared with a higher powered objective.
d. the area is the same as with a higher powered objective because the microscopes are parfocalized.

A Study of Science Understandings of Tenth Grade Biology Students as Determined by Instructional Tests

Phase I. Area I. Using the microscope in general education biology classes.

I. Background for the quiz.

A. Basic assumption:

All students enrolled in classes studying living organisms at the tenth grade level need to use the microscope to observe living and preserved biological materials.

B. Premises underlying the assumption:

1. In order to understand living organisms in many particulars (i.e., cells, microbes, tissues, fertilization, etc.) students need the direct experience of viewing some microscopic aspects of living things.

2. From the psychology of learning we know that direct experience in seeing actual living and preserved materials at the microscopic level is an important part of the variety of experiences needed to develop an understanding of such life forms.

3. To achieve an understanding of biology at the cellular, and organ and tissue levels, the direct use of the microscope is needed. Use of the microscope can contribute to understanding how scientists use instruments in their processes of inquiry and the limitations of such instruments.

C. If the basic assumption above with its underlying premises is accepted, then several questions may be raised regarding instruction in general education biology.

1. What are the minimum understandings a student must have in order to use the microscope as a scientific instrument?

2. What experiences can be developed to enable students to achieve these understandings?

3. How can the levels of understanding achieved by the students be evaluated?

4. Once evaluated, what instructional decisions might be made for the future?

D. Students in the instructional group were provided experiences including explanations and demonstrations by their teachers and Laboratory Exercise 6, "Use of the Monocular Microscope". The writer suggests that the following understandings were the more important goals of the provided instruction.

1. Proper use of the microscope.
    a. Use low power to locate the object then switch to high power if increased magnification is necessary.
        1. There is greater working distance with low power.
        2. There is a larger area of the object observed in view under low power.
    b. When using the microscope and locating the object under low power, turn adjustment screw to the stop (or until objective is just off the cover glass) and focus up.
2. The lens system effects the image of the object being viewed.
    a. Depth of field decreases with increased magnification.
    b. The image of objects are inverted and reversed by the lens system.
    c. The apparent speed of the object increases with increased magnification.
3. The size to which lenses magnify objects can be calculated.
4. The resolving power of the microscope is an extension of the human eye.

E. Following the discussion and laboratory exercise (some students had further experience in viewing Daphnia and observing the effects of substances on heart rate), a quiz was developed to evaluate levels of student understandings.

II. The Quiz.

The characteristics of the quiz are partially illustrated in the grid below. The test writer attempted to develop questions which would measure more than factual recall. Each question was classified according to Bloom's "Taxonomy of Educational Objectives." After many questions were written, ten were selected for the quiz. The election of questions was made in such a way that each area of understanding would be sampled by at least one question.

In using Bloom's "Taxonomy" for classifying any particular question, one assumes that for all categories beyond 2.00 the students have not had the specific instance in the test question as a part of their instruction. If the specific instance has been a part of the the students' instruction, the question fits into one of the subsections of 1.00.

The attached quiz on the microscope was taken by 673 students in biology classes in six high schools, in four school districts, in Los Angeles County, October, 1961. This quiz was a part of the regular classroom testing program of the teacher and was given in conjunction with a fifteen question quiz on classification plus other test items developed independently by each teacher. The test writer developed the questions from the textbook and laboratory manual used by the students. This quiz is a sample from a project on broadening the bases of evaluation in biology. No attempt is made to include all dimensions of evaluation included in the project's research design in any one instrument used in the project.

Bloom	1.00 Knowledge			2.00 Comprehension	3.00 Application
Content	1.10 of Specifics	1.20 Dealing Specifics	1.30 Universals Abstractions	2.20 Interpretation	3.00 Application
Measuring Objects	(1) (2)				
Resolving Power	(4)				
Use of the Microscope		(7)			(8)
Depth of Field			(6)		(9)
Relationships: Working Distance to Magnification				(3)	
Speed to magnification			(5)		
Area to magnification				(10)	

Figure 1. Characteristics of the Quiz.

III. Student responses on the quiz.

A. The graph below indicates the success of the students tested on the quiz.

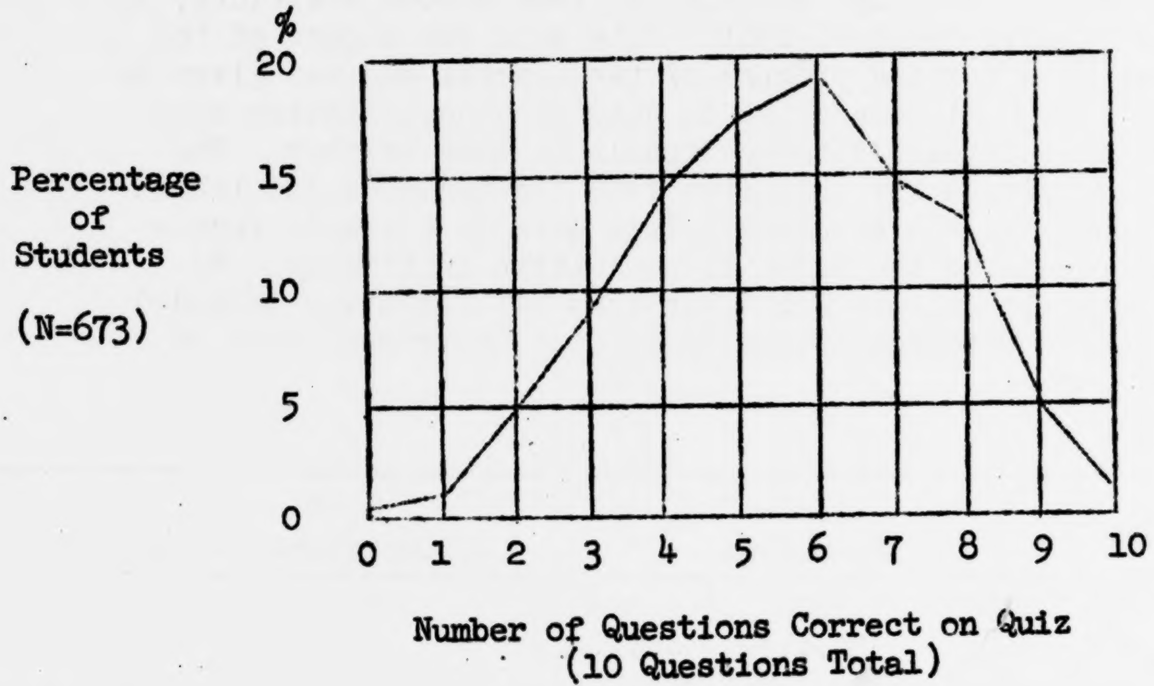


Figure 2. Frequency Distribution of Student Achievement in the Quiz.

B. The graph below indicates how successful the students were as a group on each question.

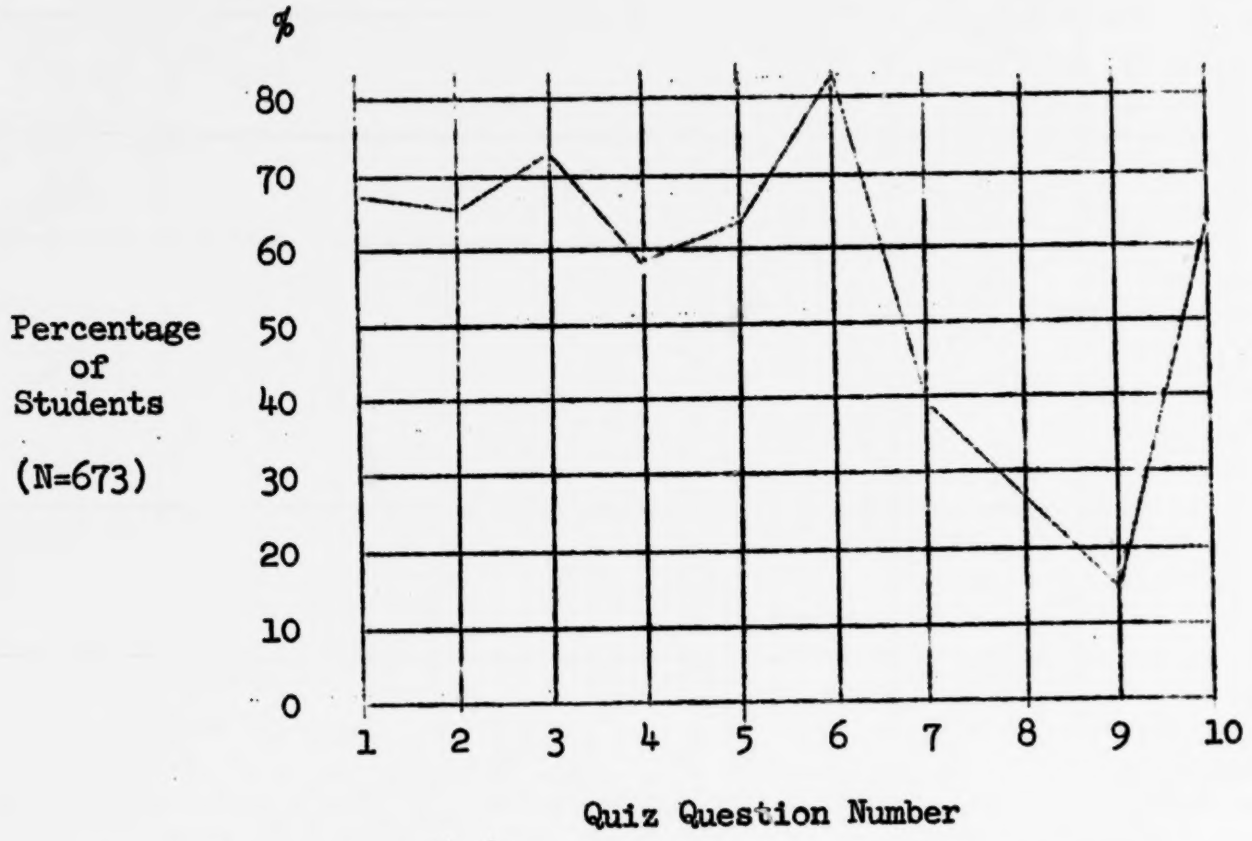


Figure 3. Percentage of Students Getting Each Question Correct.

C. The table below indicates the item responses of the students on each question of the quiz.

Responses on each question* N=673

	a	b	c	d	e	Omit
#1	13.8%	7.7%	10.2%	67.9%	0.1%	0.0%
#2	10.8	66.1	15.6	6.4	0.3	0.7
#3	18.6	72.8	5.1	3.1	0.0	0.4
#4	19.5	3.4	58.4	9.5	6.7	2.5
#5	63.5	8.8	6.2	8.6	11.9	0.9
#6	9.6	3.9	82.0	1.5	2.5	0.6
#7	12.3	22.4	12.2	38.8	8.5	3.1
#8	26.0	33.7	5.5	21.6	10.1	0.2
#9	32.8	20.5	11.3	17.1	15.2	3.1
#10	62.5	6.4	15.2	4.0	4.6	6.1

*The underlined percentage is at the correct answer to the question.

D. Percentile ranks for raw scores and statistical data.

Percentiles

10	99.0%ile
9	95.5%ile
8	87.9%ile
7	73.5%ile
6	56.4%ile
5	37.7%ile
4	22.1%ile
3	11.1%ile
2	4.2%ile
1	0.9%ile

Mean = 5.7

Median = 5^+

Standard deviation = 2.1

Kuder-Richardson Reliability Coefficient = 0.57

Standard error of measurement = 1.4

E. Can-Cannot Data.

1. Method of Determining Can-Cannot Individuals: On this ten question quiz the can-cannot groups were selected as close to the desired lower one-third and upper one-third of the total group as was possible. The CAN group are all those students who scored 7 or more questions correct. The CANNOT group are those students who scored 4 or less questions correct. By this selection process the following data were obtained:

2. Data: Can's = 228 students = 33.8%
Cannot's = 194 students = 28.8%

Item		Right	Wrong	Omit	Discrimination[1]	Ratio (Right-Wrong)	Difficulty[2] expressed as fraction of 673 responding correctly	p[3]
1	Can	212=93.0%	16= 7.0%	0	+	9:1	.68	.61
	Cannot	71=36.6%	122=63.0%	1=0.5%		1:2		
2	Can	213=93.5%	15= 6.5%	0	+	9:1	.66	.67
	Cannot	61=31.4%	132=68.1%	1=0.5%		1:2		
3	Can	216=94.7%	12= 5.3%	0	+	9:1	.73	.60
	Cannot	86=44.4%	106=54.6%	2=1.0%		1:1		
4	Can	173=75.9%	52=22.8%	3=1.3%	+	3:1	.58	.34
	Cannot	85=44.4%	100=51.6%	9=5.0%		1:1		
5	Can	204=89.5%	24=10.5%	0	+	9:1	.64	.67
	Cannot	48=24.8%	142=73.2%	4=2.0%		1:3		
6	Can	217=95.2%	10= 4.4%	1=0.4%	+	9:1	.82	.46
	Cannot	135=69.6%	56=28.8%	3=1.4%		2:1		
7	Can	159=69.8%	67=29.4%	2=0.8%	+	2:1	.39	.60
	Cannot	23=11.7%	160=82.6%	11=1.5%		1:7		
8	Can	108=47.4%	120=52.6%	0	+	1:1	.26	.43
	Cannot	24=12.4%	168=86.6%	2=1.0%		1:7		
9	Can	68=29.8%	152=67.4%	8=3.5%	+	1:2	.15	.43
	Cannot	10= 5.1%	180=92.9%	4=2.0%		1:18		
10	Can	213=93.4%	7= 3.5%	8=3.5%	+	9:1	.65	.64
	Cannot	75=38.6%	104=53.7%	15=7.7%		1:1		

[1] A plus (+) indicates a positive discriminator. A minus (-) indicates a negative discriminator.

[2] Most difficult questions approach 0.00 and least difficult questions approach 1.00. A range of difficulty is most desirable for a test, with most items having indexes in the .50 to .60 range. National Council of Teachers of Mathematics, Evaluation in Mathematics, 26th Yearbook, Washington, D. C.: The Council. p. 64

[3] Helen M. Walker and Joseph Lev. Statistical Inference. New York: Henry Holt and Company, 1953. pp. 472-475. (Reproduced by Walker and Lev from "Thorndike, R. L., Personal Selection, Test and Measurement Techniques, New York, 1949, by courtesy of John Wiley and Sons and by permission of John C. Flanagan who computed the table and distributed it privately." See note on p. 472 of Walker and Lev.)

IV. Discussion

A. Each of the ten questions in this quiz discriminated positively between the CAN and CANNOT groups. Questions #5,2,7,1,10, and 3 were the highest discriminators, each having a spread of 50% or more between the CANNOT's answering the question correctly and the CAN's who answered the question correctly. On question #9, which had the lowest (24.7%) spread between the CAN's and CANNOT's answering the question correctly and the greatest difficulty (only 15% of all students answered it correctly), one CAN in two answered the questions correctly whereas only one CANNOT in 18 answered it correctly.

B. Student responses on the quiz might be grouped around three of the goals suggested earlier in this paper.

1. To develop an understanding of the effect of the lens system on the image of the object being viewed. Questions 5,6,7,8,9 and 10 are considered to be questions directed to measuring student understanding of this goal. These questions comprised 60% of the quiz. Mean achievement of the 673 students was 48.0%.

2. To develop an understanding of proper use of the microscope. Questions 3 and 4 are considered to measure some aspects of proper microscope usage. These questions comprised 20% of the quiz. Mean achievement of the 673 students was 65.6%.

3. To develop an understanding of the size of objects being studied under the microscope. Questions 1 and 2 are considered to measure some aspects of measuring objects. These questions comprised 20% of the quiz. Mean achievement of the 673 students was 67.0%.

C. A number of questions may be raised with reference to the above data:

1. If use of the microscope is important for general education biology,

   a. were the areas selected for study the most relevant for general education students?

   b. did the balancing of the questions among content areas and cognitive levels represent the most effective selection for such a student population?

   c. is the level of achievement satisfactory on these particular test items?

   d. how may the quiz be improved as an instrument designed to measure understandings of the goals of instruction which involve the use of the microscope?

2. If greater understanding is desirable for students in general education biology, what patterns of time and instructional experiences might assist in maximizing student learnings?

3. Do the instructional goals as stated provide an adequate statement upon which to build a test in this instructional area--use of the microscope in general education biology?

4. Are the statistical summaries and interpretations provided an effective and informative review of the data and are they sufficient to the conclusions? Are there other more productive methods of analysis--productive in the sense of assisting classroom teachers in securing relevant meanings from such a test analysis?

5. With what characteristics of the student population, teaching methods, etc., might the data be correlated to increase yield of meanings?

6. If a priority of behavioral objectives were to be developed for this area of scientific skill, what would be criterial understanding for each quartile of the total possible range of tenth graders--from those in the lowest quartile who may have the lowest potential for scientific literacy to those in the top quartile who may have the highest potential for scientific literacy?

    a. Does the present quiz seem to make effective discriminations along this continuum? If not, how might its discriminative effectiveness be increased?

    b. What would be criterial achievement expectations for any student who was to be considered to have secured a minimum adequacy of understanding about the use of the microscope?

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JTR:dv (3-16-62)

APPENDIX B

(1) Biology Questionaire

(2) Fast Answer Card

BIOLOGY QUESTIONAIRE

School ______________________________ Teacher ____________________

Date _______________________ Period ____________________

Name ______________________________ Year in School __ Boy__ Girl __

Last, First, Initial,(Nickname)

___________________________________ Date of Birth ______________

Address

Father's Occupation ______________________________

Mother's Occupation ______________________________

1. What would you like to be doing 10 years from now?

2. What school subjects are at present of most interest to you?

3. What school subjects are at present of least interest to you?

4. What school subjects are most difficult for you?

5. In what sports do you participate?

6. List, in order, the things in which you spend the greatest amount of time out of school.

7. If you have 1/2 hour in which you have nothing to do, what do you usually choose to do?

8. On what hobbies do you spend time?

9. What magazines do you regularly read?

10. How often do you go to the movies? (monthly)

11. How often do you go to the theater (plays, ballet, symphonies, etc.)? (monthly)

12. In what school clubs do you participate?

13. What organizations do you belong to out of school?

14. Do you have a personal library? If so, how many volumes?

15. Do your parents have a library? If so, how many volumes?

16. To what radio programs do you listen regularly?

17. What TV programs do you watch regularly?

18. What previous sciences have you taken?

7th grade ______________________________ Hours per week ______
No. of Semesters ______

8th grade ______________________________ Hours per week ______
No. of Semesters ______

9th grade ______________________________ Hours per week ______
No. of Semesters ______

10th grade ______________________________ Hours per week ______
No. of Semesters ______

11th grade ______________________________ Hours per week ______
No. of Semesters ______

19. Schedule of classes for this year:

____

____

____

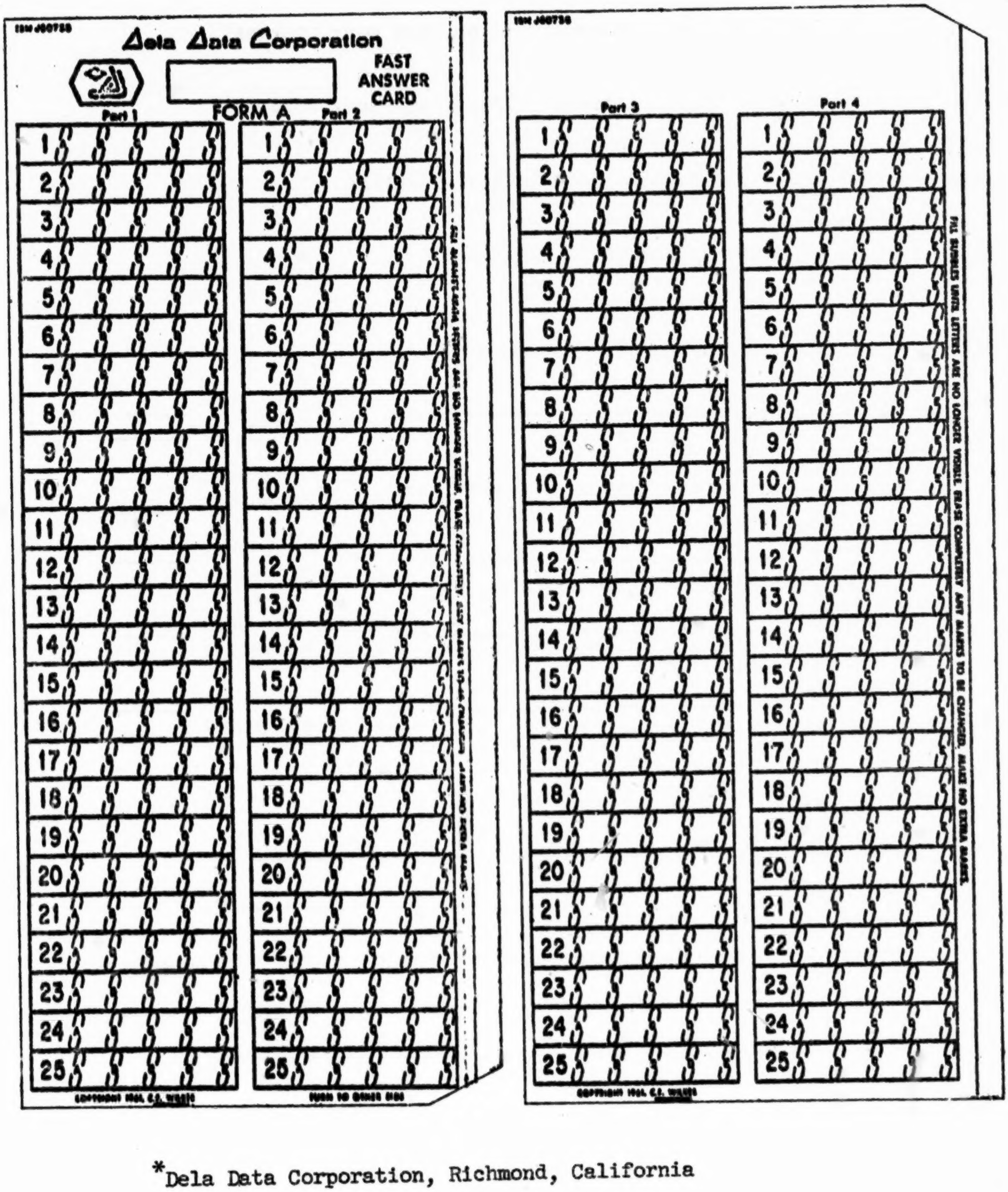
____

____

____

____

Answer Cards Used for Tests 43-55*



Dela Data Corporation

FAST
ANSWER
CARD

FORM A

Part 1	Part 2	Part 3	Part 4
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9
10	10	10	10
11	11	11	11
12	12	12	12
13	13	13	13
14	14	14	14
15	15	15	15
16	16	16	16
17	17	17	17
18	18	18	18
19	19	19	19
20	20	20	20
21	21	21	21
22	22	22	22
23	23	23	23
24	24	24	24
25	25	25	25

FILL BUBBLES UNTIL LETTERS ARE NO LONGER VISIBLE. ERASE COMPLETELY ANY MARKS TO BE CHANGED. MAKE NO EXTRA MARKS.

*Dela Data Corporation, Richmond, California

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